SOLAR PHYSICS COMMITTEE.

- 12763 -

A DISCUSSION OF AUSTRALIAN METEOROLOGY

Being a Study of the Pressure, Rainfall and River Changes, both Seasonal and from Year to Year, together with a Comparison of the Air Movements over Australia with those over South Africa and South America.

BY

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UNDER THE DIRECTION OF

Sir NORMAN LOCKYER, K.C.B., LL.D., Sc.D., F.R.S.

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LIST OF PUBLICATIONS OF THE SOLAR PHYSICS COMMITTEE

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	Year of Publication.
Preliminary Report of the Committee on Solar Physics	(1880)
Report by the Committee on Solar Physics	(1882)
Second Report by the Committee on Solar Physics	(1889)
Positions and Areas of Sun Spots and Faculæ, 1887 and 1888	(1889)
,, ,, ,, ,, ,, 1889	(1891)
,, ,, ,, ,, ,, 1871–1881 (inclusive) and 1890	(1892)
,, ,, ,, ,, ,, 1891	(1894)
,, ,, ,, ,, ,, 1892	(1895)
,, ,, ,, ,, ,, 1893	(1896)
,, ,, ,, ,, ,, 1894, 1895, 1896, and 1897	(1899)
Spectra of Sun Spots, 1879–1897 (inclusive)	(1900)
Positions and Areas of Sun Spots and Faculæ, 1898 and 1899	(1901)
Catalogue of 470 of the Brighter Stars	(1902)
The Sun's Spotted Area, 1832–1900	(1902)
Positions and Areas of Sun Spots and Faculæ, 1900, 1901, and 1902	(1904)
Mean Annual Variations of Barometric Pressure and Rainfall	(1905)
Positions and Areas of Sun Spots and Faculæ, 1903 and 1904	(1906)
Tables of Wave-lengths of Enhanced Lines	(1906)
Spectroscopic Comparison of Metals present in certain Terrestrial and Celestial Light-sources (with special reference to Vanadium and Titanium)	(1907)
Report of the Solar Eclipse Expedition to Palma, Majorca, August 30th, 1905	(1907)
Positions and Areas of Sun Spots and Faculæ, 1905	(1907)
Monthly Mean Values of Barometric Pressure for 73 selected Stations over the Earth's Surface	(1908)
On the General Spectra of certain Type-Stars and the Spectra of several of the Brighter Stars in the Green Region	(1908)

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PREFACE.

This memoir, like the previous one, deals with the coincidence of solar and terrestrial changes. In the volume entitled "Monthly Mean Values of Barometric Pressure for 73 selected Stations," which was published by the Solar Physics Committee in 1908, I gave on Plate 9 curves representing the pressure changes over Australia from year to year, which indicated a variation of about four years' duration, a period already found in India and South America, and corresponding with the curve of prominence frequency.

In a paper communicated to the Royal Society in 1906 Dr. Lockyer pointed out that long-period barometric changes, similar in period but different in phase, occurred in South America and Australia.

In consequence of the discovery of the inversions between South America and India, it seemed important to discuss specially the Australian conditions, with a view of seeing the points of similarity and difference in these three regions.

This inquiry was entrusted to Dr. Lockyer, who has been assisted by Messrs. Moss and Connolly.

Difficulty has been found in getting together the requisite meteorological data, and the memoir has in consequence taken about $1\frac{1}{2}$ years to complete.

NORMAN LOCKYER.

Solar Physics Observatory,
October 1908.

INTRODUCTION.

INTRODUCTION.

In a series of communications to the Royal Society Sir Norman Lockyer and I have pointed out* the presence of a barometric see-saw of short duration (about 3·8 years) which is nearly world-wide in extent. In the last two papers it was shown that the pressure changes occurring from year to year in Australia were very closely similar to those taking place in India.

The world-wide nature of such pressure changes has more recently (1908) been published in detail in a volume† entitled "Mean Monthly Values of Barometric Pressure for 73 selected Stations over the Earth's Surface." This volume, issued by the Solar Physics Committee, was compiled at the Solar Physics Observatory, and contains not only the mean monthly values of pressure for each year, extending over a long series of years, but curves for each station showing the changes which occur from one year to another.

In a subsequent communication to the Royal Society‡ I referred again to this variation of the mean annual pressure values in operation in Australia, and directed attention to the fact that the mean amplitude of the Australian variation was nearly double that of the Indian change. I further showed that this Australian pressure change amounted to nearly 35 per cent. of the mean annual variation, and must therefore play an important part in bringing about changes in the weather experienced from year to year. In the case of the pressure variation of long duration in operation in Australia, I pointed out also that this fluctuation took about 19 years to complete a cycle, and its amplitude reached nearly 25 per cent. of the annual variation.

The importance of these changes, their possible periodicity, and their extensive distribution, suggested that a more detailed enquiry into the Meteorology of Australia as a whole might be useful.

Such an investigation is now presented in the present memoir, and the lines on which it is written are as follows:—

Commencing with a brief account of the similar barometric changes which occur over the whole of Australia from year to year (Chapter I.), and which suggested the present investigation, a general survey of the main features of Australian meteorology (Chapter II.) is then summarised. The mean annual pressure and rainfall variations are then individually dealt with and compared (Chapters III.–V.) in order to determine their seasonal distribution. Comparison is next made with the changes from year to year of the pressure and rainfall

* Roy. Soc. Proc., Vol. 70, page 500, 1902.
Vol. 71, page 134, 1902.
Vol. 73, page 457, 1904.

† Wyman and Sons, Ltd., London, 1908.

‡ Roy. Soc. Proc., A., Vol. 78, page 43, 1906.

(Chapter VI.), and here also are brought together some deductions with regard to the frequency of "southerly bursters." The variations in the heights of the river gauge readings, situated on the Darling and Murray rivers, are brought in as evidence (Chapter VII.) to corroborate the rainfall changes. Chapter VIII. summarises the results obtained from the data employed to determine changes of long duration from barometric and rainfall statistics.

The relation of Australian pressure changes to variations in other parts of the world, chiefly South America, South Africa, and India, is discussed in Chapter IX., while in Chapter X. some facts are brought together in which an attempt is made to point out the similarity of air movements over South America, South Africa, South Indian Ocean, and Australia.

The whole discussion is based chiefly on the comparison of curves, but the data from which they have been made are given in detail in the Appendix for reference.

In the preparation of this memoir one has learnt to fully appreciate the magnificent work of the late Mr. H. C. Russell, whose untiring labour in the domain of Australian meteorology on a wide basis, has done so much not only to collect statistics but to promote discussions of data, and thereby advance the knowledge of the behaviour of the movements of the atmosphere in that part of the world.

When the MSS. of this memoir was completed and about to be sent to press, Mr. H. A. Hunt, the Commonwealth Meteorologist, arrived opportunely in London. Advantage was taken of his presence in this country to submit the memoir to him for any observations or criticisms he might like to make. Mr. Hunt very kindly read it carefully through and made many very valuable suggestions, which have been embodied in the work. I take this opportunity, therefore, of expressing to him my sincere thanks, not only for the suggestions made, but for the time he has spent in examining the MSS. and plates.

I am indebted to Mr. J. B. Henderson, M.Inst.C.E., Government Hydraulic Engineer of the Queensland Water Supply Department, Brisbane, for statements of the rainfall at sixteen and of barometric pressure at seven representative recording stations in Queensland for the period 1896 to 1905, both years inclusive.

Dr. W. N. Shaw, the Director of the Meteorological Office, London, has greatly assisted in the work by permitting Australian data existing in his office to be copied, and I take this opportunity of expressing my thanks to him.

My best thanks are also due to Commander M. W. Campbell Hepworth, C.B., for allowing me to reproduce his maps showing the results of his investigations on the tracks of cyclones and anticyclones over the Australian area. The observations and discussions he has made, especially over the Cape to Australia shipping routes, have considerably helped to decipher the wind systems involved on this large expanse of ocean.

Among other authorities whose publications have been consulted may be mentioned Sir Charles Todd and Mr. Ernest Cooke, Government Astronomer at the Perth Observatory, for Australia; Mr. Charles M. Stuart, the Secretary of the Meteorological Commission, Cape Colony, and Mr. R. T. A. Innes, Government Meteorologist, for South Africa.

The necessary preparatory abstracts of the data, computations, and reductions have been made by Messrs. W. Moss and T. F. Connolly, computers in the Observatory, and they have assisted also in the preparations of the diagrams and plates. Mr. J. P. Wilkie reduced photographically the original diagrams and curves for the press.

Attention may be drawn to the fact that the great hindrance met with in undertaking this investigation has been the difficulty of obtaining the necessary data. If the data did not exist one would bow to the inevitable; but they do exist in considerable quantity, although to a large extent they remain unpublished.

Thus, in the case of Queensland, a most important area for the study of Australian weather changes, and where meteorological observations have been made for a considerable number of years, the only observations that could be utilised in this enquiry extend from 1896 to 1905, a period of 10 years. Even these had not been published, but were sent in manuscript form on application.

To foster the study of Australian weather among workers both in an out of this continent, it seems, therefore, most desirable that the observations, on which so much time and money have been spent, should be published as soon as possible, for the utility of such observations depends on their quick dissemination and accessibility.

Now that the Meteorological Service has been organised on a general basis and a central bureau established, it is to be hoped that the long-wished-for publication of past data will soon take place, so that they may become available to investigators.

One may conclude this introduction by quoting the words of the late Dr. Alexander Buchan, M.A., LL.D., F.R.S., in his discussion of the circulation of the atmosphere, based largely on the meteorological observations made on board the "*Challenger*" (Report on Atmospheric Circulation, page 69, "Challenger" Reports, Vol. II., Part V. Edinburgh, 1889):—

"The most important weather changes, as affects human interests, are those which depend on wind, temperature, and rain; and as these again are most intimately bound up with the actual distribution of pressure at the time, it is the last that really furnishes the key to weather changes."

Chapter I.

THE BAROMETRIC CHANGES FROM YEAR TO YEAR.

THE BAROMETRIC CHANGES FROM YEAR TO YEAR.

In the papers which have been referred to in the introduction it was stated that the pressure changes in Australia from year to year were closely similar to those occurring in India. This statement was based chiefly on the examination of the Australian records of Perth, Adelaide, Melbourne, and Sydney, which stations represent a great length of longitude but little latitude.

As the area of Australia is nearly 3,000,000 square miles, or about three-quarters the size of Europe, the first step in the investigation was to see whether this pressure variation of short duration was similar all over the country. It was necessary, therefore, to collect as many series of available observations of pressure extending over as many years as possible from stations situated in many different regions and to compare them among themselves.

Twenty well scattered stations were eventually analysed from this point of view, and the curves illustrating the changes from year to year were found to be very similar.

For the following stations the records in the form of curves are here given (*see* Plate 1):—Port Darwin, Daly Waters, York, Carnarvon, Albany, Eucla, Melbourne, Deniliquin, Sydney, Goulburn, Port Augusta, Adelaide, and the annual mean values are brought together in the Appendix (Table 1). In the cases of the stations, Alice Springs, Perth, Bathurst, Cape Borda, Esperance, Freemantle, Cossack, and Derby, no curves have been reproduced here.

Thus Port Darwin and Daly Waters represent the changes occurring in the northern part of the northern territory of South Australia; York and Carvarvon the west, and Albany and Eucla the south of Western Australia; Melbourne and Deniliquin represent Victoria; Sydney and Goulburn represent New South Wales; while Port Augusta and Adelaide represent the southern portion of South Australia. The Bombay pressure curve is added at the bottom of the set of curves for comparison.

An examination of these curves indicates clearly that simultaneous excess high or low pressure in any one year is a *marked feature of the whole of the Australian Continent*, and is not restricted to any particular portion of this area.

It is possible also to determine the approximate relative magnitudes of these changes for this region. This can be done by finding the differences in the barometric readings between several pronounced minima in the curves and the next following maximum. The mean values for these amplitudes so determined for three stations are as follows:—

Melbourne - - - - - -	0·076 inches.
Adelaide - - - - - -	0·077 ,,
Sydney - - - - - -	0·071 ,,

The mean for the three stations being 0·074 inches.

The individual years taken and the corresponding barometric readings employed were as follows :—

Station.	Year.	Minimum.	Year.	Succeeding Maximum.	Difference.
		Inches.		Inches.	Inches.
Melbourne - -	1863	29·896	1866	29·954	
	1875	29·886	1877	29·993	
	1878	29·905	1881	29·966	
	1882	29·902	1885	29·996	
	1890	29·924	1891	29·985	
Mean - -	—	29·903	—	29·979	0·076
Adelaide - -	1863	30·006	1865	30·073	
	1875	30·028	1877	30·144	
	1879	30·052	1881	30·107	
	1882	30·047	1885	30·121	
	1890	30·036	1891	30·111	
Mean - -	—	30·034	—	30·111	0·077
Sydney - -	1867	29·872	1868	29·933	
	1875	29·803	1877	29·896	
	1879	29·816	1881	29·874	
	1882	29·829	1885	29·920	
	1893	29·829	1894	29·885	
Mean - -	—	29·830	—	29·901	0·071
General Mean - -	—	—	—	—	0·074

We are thus confronted with a very considerable change of pressure over the whole of Australia from one year to another, and its effect on the weather must be very significant and therefore worth investigation.

In Table 2 (Appendix) are brought together the mean monthly and annual pressure values for Perth, Melbourne, Sydney, and Adelaide, four excellent series of observations.

Before, however, dealing with the changes from one year to another, it is necessary to study in the first instance the general conditions of pressure and rainfall change during a year, prefacing these remarks with a brief description of the main features of Australian meteorology.

Chapter II.

GENERAL FEATURES OF AUSTRALIAN METEOROLOGY.

GENERAL FEATURES OF AUSTRALIAN METEOROLOGY.

Before proceeding to describe in detail the curves representing the pressure changes throughout the course of a year, it is necessary, in the first place, to gain some notion of the leading features of Australian meteorologial conditions. These have been very clearly described by the late Mr. H. C. Russell,* and reference will be briefly made here to the more salient points.

Australian weather, according to him, is the product of a series of rapidly-moving anticyclones, or high-pressure areas, which follow one another with "remarkable regularity" and are the great controlling force in determining local weather. These anticyclones move from west to east at an average rate of about 400 miles a day. About forty-two pass over the continent in the course of a year, the average transit over any place being in summer seven and in winter nine days. The average time of passage over any place he gives as 8·7 days.

In their passage across the continent the centres are not always in the same latitudes, but vary according to the time of the year. Thus Mr. Russell has shown that in the Australian summer months, *i.e.*, from October to March, the mean latitude of their paths is about 37° to 38°, while during the winter months, April to September, they lie about latitudes 29° to 32°.

Another important feature of these high-pressure areas is that during the winter months they are very much larger than they are in summer, and very commonly, we are told,† "their area is equal to Australia, and their control of the weather more complete than it is in summer."

In form the anticyclone is generally elliptical, the axes being in the relation of about 2 to 1, with the longer axis directed east and west. So long as the anticyclone is passing over the flat lands, this shape is generally maintained, but as soon as the east coast range of mountains is reached the major axis becomes shortened and turned more in a north to south direction.

As these anticyclones pass in rapid succession eastward, **V**-shaped depressions or cyclones follow in their wake both north and south of them. These "lows" are, as Mr. Russell states, "tied to the anticyclones as effect is to cause," so that they partake of the movement of translation of the anticyclones. The tendency of these lows is to wedge themselves in between the anticyclones, and they sometimes succeed in passing in between them travelling south-easterly or north-easterly according as to whether they come from the northern or southern side of the anticyclones respectively.

The accompanying four charts, Fig. 1, will serve to show various types of anticyclonic and cyclonic conditions over Australia. These maps have been

* "Three Essays on Australian Meteorology." Hon. Ralph Abercromby. [Sydney, 1896.]

† *Ibid.*, page 96.

selected and redrawn from the very excellent series of charts given by Mr. Henry A. Hunt in his essay on "Types of Australian Weather."*

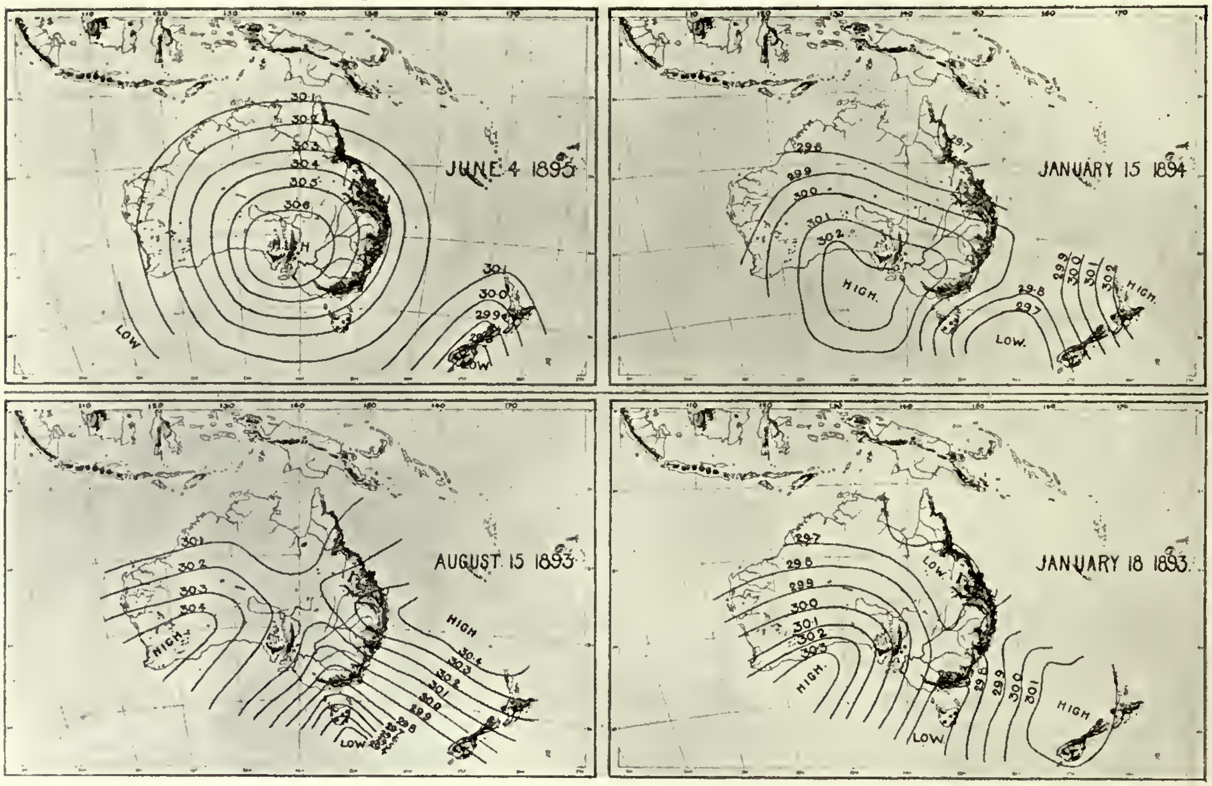


Fig. 1.

The general direction of motion of the southern "lows" is from west to east. The northern or tropical "lows," or tropical north-easters and north-westers, also have a general movement in the same direction; these last-mentioned "lows" originate from the southerly extension of the monsoonal low-pressure region, coming from the north-east, curling round towards the south, and eventually taking an easterly or south-easterly course. In the north-eastern part of Australia they are known as tropical north-easters, and in the north-west part as tropical north-westers.

From the above it will be gathered that as the anticyclones vary their latitude during the course of a year, the northern and southern "lows" follow suit. As Australia lies between the parallels of latitude of 10° S. and 40° S., the anticyclones pass along the south coast during the summer months (October to March). The tropical or monsoonal "lows" can therefore extend over a great portion of the northern part of Australia during this season, while the southern "lows" are kept well out to sea in the southern ocean.

In the winter months (April to September), on the other hand, the tracks of the anticyclones are in lower latitudes or nearer the Equator. At this season the

* "Three Essays on Australian Weather." by Hon. Ralph Abercromby. [Sydney, 1896.]

tropical "lows" can scarcely approach the northern part of this continent, while the southern "lows" can freely skirt the south coast.

It is to be noted that although the general seasonal movements of the low-pressure disturbances are as described above, it occasionally occurs that a monsoonal "low" breaks through and reaches quite southerly latitudes in the winter season, and that a southerly "low" travels to more northerly latitudes during the winter season.

In the case of this apparently unseasonal movement of the monsoonal "lows," Mr. Ernest Cooke, Government Astronomer at the Perth Observatory, directed attention to this in his report for the year 1904. Thus, in his notes for the month of July 1904, he wrote (page 13):—

"This month's meteorology has been specially interesting, because it appears to have thrown fresh light upon the path of our winter storms prior to their arrival at Cape Leeuwin. Hitherto it has been generally supposed that the "lows" which sweep along the Southern Ocean from the Leeuwin to Tasmania had previously travelled eastward from South African longitudes, and they have frequently been spoken of by both African and Australian meteorologists as northerly extensions of the normal low pressure which is supposed to exist in the Antarctic regions. Efforts to trace these storms from Africa to Australia have failed, and it will be seen from the following extracts that this month's observations give support to the theory that these winter disturbances are true cyclones, which travel down the Indian Ocean and appear to be very similar to the summer storms, except that as a general rule the track of the winter cyclones is well to the westward of our coast, and we do not perceive their approach until they are close to the Leeuwin. If this theory turns out upon further investigation to be correct, it will at times render valuable assistance to the forecaster, for indications of the approach of a storm from the ocean may frequently be obtained from north-west coastal reports, a direction whence indications have generally been overlooked."

The above remarks indicate therefore that while the normal state of things during the winter months is a series of low-pressure areas originating from southern latitudes, the occasional advent of "lows" from the tropics, which curl in their path and strike the south-west coast of Australia, must not be lost sight of if the observations of Mr. Cooke are corroborated.

Important and independent evidence of the changes in the latitude of the paths of the anticyclonic systems passing over Australia has also been given by Commander M. W. Campbell Hepworth, C.B.*

As a matter of historical interest it may here be mentioned that both Russell's and Hepworth's papers were communicated to the Royal Meteorological

* "*The tracks of ocean wind systems in transit over Australasia.*" Quart. Jour. R. Met. Soc., Vol. XIX., No. 85, January 1893, page 34.

Society about the same time, the latter's arriving first. They were, however, both read at the Society on the same evening.

In Hepworth's investigation a close study is made of the daily weather charts of Australia and New Zealand for the year ending September 1891. The results deduced are closely similar to those obtained by Russell. Although the author does not state any values as to the mean latitudes of the tracks for each of the seasons winter and summer, he accompanies his remarks with four very excellent maps which show clearly the general paths of the centres of these wind systems. With Commander Hepworth's permission these maps are reproduced here, Fig. 2, and they indicate better than words the main features under discussion.

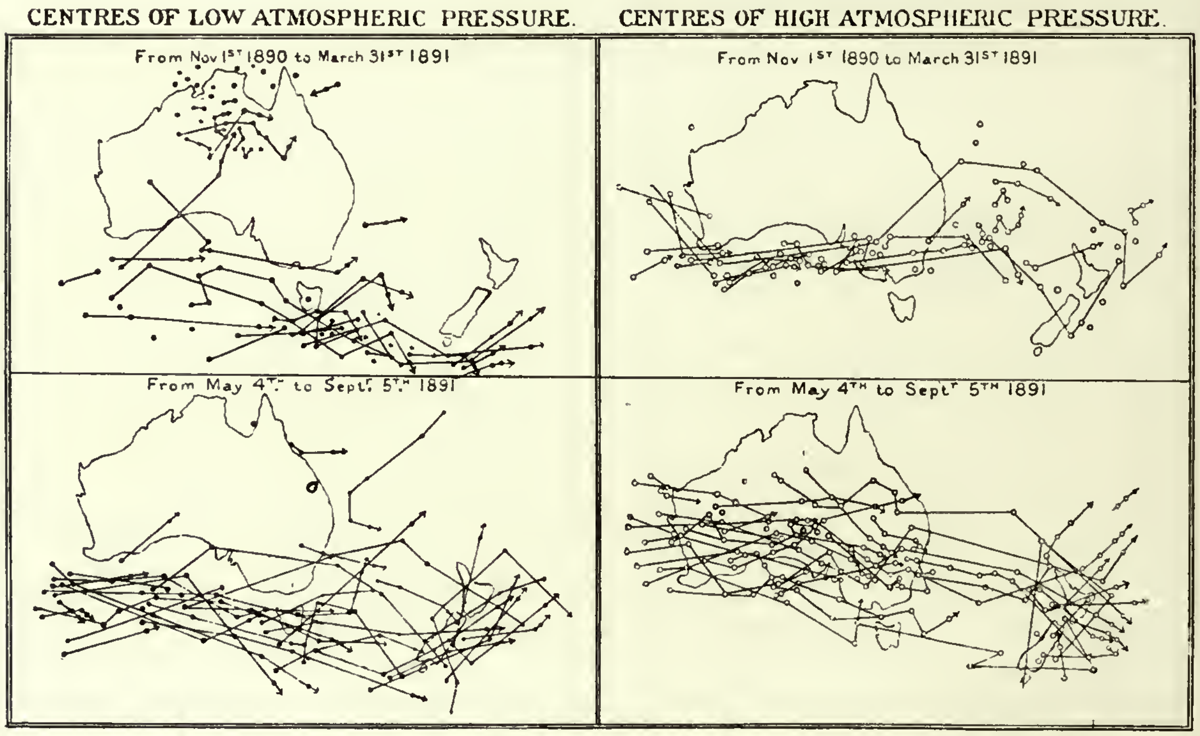


Fig. 2.

In the summer months, November to March, it will be seen that the paths of the anticyclones pass chiefly over the southern coast of the Australian continent. Their southerly latitude prevents the southerly lows from reaching the coast of Australia, and the tracks of the centres of low pressure on the other maps for the same period show this very distinctly. An opportunity is thus afforded for the monsoonal lows to reach the northern part of Australia, and the numerous black dots showing the centres of low pressure in this region indicate their great frequency about this period of the year.

Turning to the other two maps which present the condition of things during the winter months, May to September, it will be seen that the centres of high pressure pass well over Australia, that is, their mean southerly latitude is con-

siderably reduced. In consequence of this, the southern lows take a more northerly course, as is shown in the maps showing the centres of low pressure for this period. It will be noticed further that practically no low-pressure centres are recorded at the northern part of Australia, and this is due to the barring influence of the high-pressure areas, which prevent the monsoonal lows from reaching the coast.

It will thus be seen that this seasonal change of latitude of the high-pressure areas with their attendant low-pressure areas on their northern and southern sides is a dominant factor in Australian weather throughout a year.

In another illustration (Fig. 3) an attempt has been made to indicate on one map some of the main points to which reference above has been made. Thus the

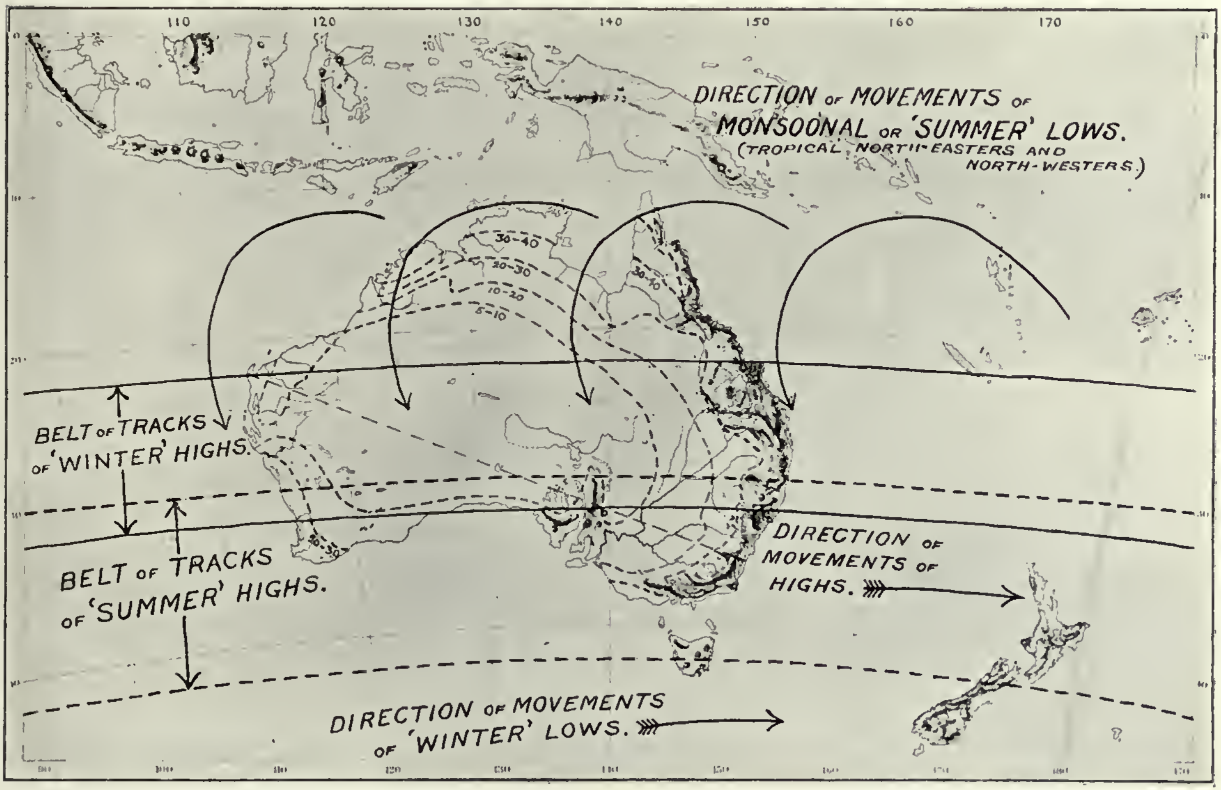


FIG. 3.

mean tracks or belts of the centres of the winter and summer "highs" are represented by continuous and dotted lines respectively. The directions of the winter and summer "lows" are also shown, the former travelling from west to east, while the latter recurve from a south-easterly to a north-westerly course, and reach the north-east coast as "tropical north-easters," and the north-west coast as "tropical north-westers."

While dealing with the subject of the general features of Australian meteorology, and having previously indicated that the mean annual pressure over the whole continent varies very considerably from one year to another, it is important to find out the chief characteristic features which have been noted during these exceptional years of high and low pressure.

For the purpose of this inquiry the annual volumes of the "Meteorological "Observations made at the Adelaide Observatory and other Places in South Australia "and the Northern Territory" have been utilised. An attempt was first made to take the years of exceptionally high and low pressure, and extract statements which would indicate the general conditions of the anticyclones or cyclones during these years. Such characteristic features as were sought for were not found recorded in the earlier volumes, the remarks being confined chiefly to more detailed barometric changes.

The desired statements were, however, found in the report for the year 1891, a year of exceptionally high pressure. One may therefore assume that the experiences recorded in this year may be considered as typical of all high-pressure years.

The extracts from the Monthly Summaries are as follows, the most important points being printed in italics:—

> Page 13. February. "As regards the weather generally during the month, the extreme dryness was doubtless due to the high pressure which prevailed. The Colony seems to have been protected, as it were, from the influence of south coast disturbances *by a belt of high pressure covering* the Bight and southern parts of the Colony. At times the barometer within this belt read as high as 30·2 and 30·3 inches, but even when they were only relatively high (as 30·0 inches) it offered an *impenetrable barrier to the low-pressure energy in the south* . . . ."
>
> Page 29. April. "All along the southern seaboard of the continent there has been this month an almost *unbroken continuance of high-pressure conditions. Anticyclonic 'centres' passed, from time to time, eastward* from the Great Bight to New South Wales or Tasmania . . ."
>
> "At the end of the month the maximum pressure was reached, *a vast mound or mountain of pressure being steadily built up* during the last few days reaching its maximum on the last day, *when the whole of Australia, Tasmania, the Southern Ocean, the Pacific Ocean nearly to New Zealand, and the Indian Ocean to the west of the continent* (or some 50° of longitude and 35° of latitude) *were enclosed within the isobars of one vast high-pressure system.*"
>
> Page 37. May. "May was characterised by *intense* and *prolonged high-pressure conditions.* . . ."
>
> "This month the dry area embraced the whole of the Colony. . . ."
>
> "*This anticyclonic belt, or ridge of high barometers* over the southern coast line of the continent, lasted nearly all through May, and, as is usually the case, acted as an *effectual barrier to low-pressure extensions* from the Southern Ocean . . ."
>
> "The maximum point the pressure reached was 30·664 inches on the 1st, when the *vast high-pressure system,* which steadily formed during the last few days of April, still covered the continent."

Page 53. July. "The character of the weather charts then completely altered—the *large anticyclonic systems*, which were *so marked a feature of the previous months*, again covering the continent."

Page 61. August. "The most marked feature of the month was again its dryness and *exceptionally high barometric conditions*."

"Looking through the daily weather charts for the month, the most noticeable feature is the *large number and extent of the anticyclonic systems which passed over the continent—at times the whole continent and the surrounding oceans, even including New Zealand, being enclosed within the isobar of one vast high-pressure system*—within the central area of which the barometer read as high as 30·5 and 30·6 inches. Those *large systems* have been *a striking feature of the weather charts all through this winter season*, and special attention is called to the circumstance as associated with the exceptional character of the season, as regards the small, variable, and light rainfall, especially over the southern portions of the Colony."

Page 69. September. "Continued dry weather was the chief feature of the month . . ."

"The pressure was *very high* through the latter part (or during the last ten days) of the month. . . ."

Page 85. November. "November was dry with rather high barometric pressure . . ."

". . . During the remainder of the month, a high-pressure system gradually formed over the Southern Ocean, extending over the greater part of the continent . . ."

Page 94. Summary for the year. "As far as the southern districts are concerned, this year will rank amongst the *driest years experienced* . . ."

"One striking feature of the year was the absence of general soaking rains."

From the above extracts it will be gathered that the chief characteristics which can be attributed to this high-pressure year are:—

1. Greater size of anticyclonic systems.
2. Fewer number of low-pressure areas.
3. Great deficiency of rainfall.

By plotting the values for the daily means of pressure for Adelaide, day by day, for several of the high-pressure months referred to above, it is observed that the progressive movements of the anticyclones from West to East is still in evidence, though their motion seems to be slower. It does occur sometimes that

the anticyclones move very slowly and become even stationary; and this fact was clearly stated by Russell* in the following words:—

"Another feature brought out in the diagrams is the occasional stoppage of the anticyclones. . . . Out of a total of 42 anticyclones which passed over Australia in 1891, 6 or 15 per cent. hesitated or actually stopped in their forward motion."

It is interesting to note that the year 1891 was one of excessively high pressure, so that such an occurrence of this hesitation or stoppage may be a feature of the anticyclones during these epochs. It will be shown, however, later on (page 29), that the number of anticyclones per year does not seem to alter much, and Russell also came to the same conclusion.

One may conclude, then, that such years as 1877, 1881, 1885, 1888, and 1891, which were years of very excessive pressure, were caused by the anticyclones having altered their *normal condition* and become, on the average, *very much larger*.

During these epochs they presented very formidable barriers to the inroads of the low-pressure systems, both on their northern and southern boundaries, and thus prevented these rain-bearing systems from watering the country. High-pressure years should therefore be years of deficient rainfall over the *whole* of Australia.

If, now, the Adelaide Annual Meteorological Reports be examined for those years when Australia was undergoing a great deficiency of pressure, it will be found that such large anticyclonic systems, as have been referred to above, are more the exception than the rule, and that the Colony is frequently swept by the low-pressure areas, as will be shown in a subsequent chapter (page 29).

As low-pressure areas are closely associated with rainfall, low-pressure years should be wet years for the whole of the Colony.

It is possible that the above statement, associating high-pressure years with years of deficient rainfall over the whole of Australia, may require to be slightly modified when more rainfall statistics over a greater area of Australia become available. Only a small amount of rainfall data can at present be utilised for the important and large State of Queensland, since they are as yet unpublished. With regard to the year (1891) in question, Mr. Hunt has informed me that—

"1891 was not a year of marked deficiency of rainfall in the Eastern States, and although the absence of remarkably heavy daily falls in New South Wales was conspicuous in South Australia, yet, in Queensland, Ayr had 10·19 inches on March 25th, Burketown 13·58 inches on June 15th, Cairno 14·08 inches on

* Quart. Jour. R. Met. Soc., Vol. XIX., No. 85, January 1893, page 26.

April 5th, Donaldson 11·29 inches on January 27th, Cloncurry 10·33 inches on January 23rd, Townsville 10·61 inches on March 28th, and Mackay 10·39 inches in March."

In this memoir the Queensland rainfall statistics which have been employed extend only from 1895 to 1906, the only data which could be obtained from Australia, so that no discussion has been possible with respect to the previous years, including 1891. These when properly grouped together and compared with the pressure changes, as is done on page 48, indicate clearly that the low-pressure years are years of increased rainfall and *vice versâ* in Queensland.

Chapter III.

THE MEAN ANNUAL PRESSURE VARIATIONS.

THE MEAN ANNUAL PRESSURE VARIATIONS.

After the preliminary remarks, given in the last chapter, concerning the general atmospheric movements which take place over Australia, the curves representing the mean annual pressure variations can be better interpreted.

In order to select stations well distributed over the land area, and which present satisfactory series of observations, the following places given in the accompanying table have been chosen. The respective columns show the States and Districts, the names and latitudes of the stations used, and, finally, the number of years over which the observations here utilised extend:—

State.	District.	Station.	Lat. S.	No. of Years.
South Australia - -	N.	Port Darwin - -	12° 28′	24
West Australia - -	N.	Wyndham - -	15 20	9
" " - -	N.	Derby - - -	17 20	11
" " - -	N.W.	Cossack - -	20 40	7
South Australia - -	Central	Alice Springs - -	23 38	23–24
West Australia - -	W.	Carnarvon - -	24 50	11
" " - -	W.	Geraldton - -	28 40	13
" " - -	S.W.	Perth - -	31 57	15
" " - -	S.W.	Bunbury - -	33 20	15
New South Wales -	Coast	Sydney - -	33 52	28
South Australia - -	S.	Adelaide - -	34 57	41
Victoria - - -	—	Melbourne - -	37 50	43

The curves representing the mean annual variations for these stations are shown in Fig. 4, the values from which they have been drawn being given in the Appendix (Table 3).

The main feature of these curves, which is common to them all and to which attention is first drawn, is that all the curves have one principal minimum. For the higher latitudes this minimum occurs in December, while, as the equator is approached, it is more distinctly pronounced in January.

The second prominent trait is the double maximum in April and July in the stations which have high latitudes, and the single maximum in July in the lower latitudes. It is worthy of notice to observe the gradual change from the double to the single maximum as the more equatorial regions are reached, and also the less rapid descent after July of the more southern stations.

The form and changes of type of these curves seem to be simply and efficiently explained by the change of declination of the sun throughout the year. In the Australian region of the world, places which have the sun in the zenith at noon are dominated by a region of low pressure, a region in which the monsoonal "lows" occur. Bordering on this low-pressure region and on the southern side of it are found the anticyclones which pursue their west to east

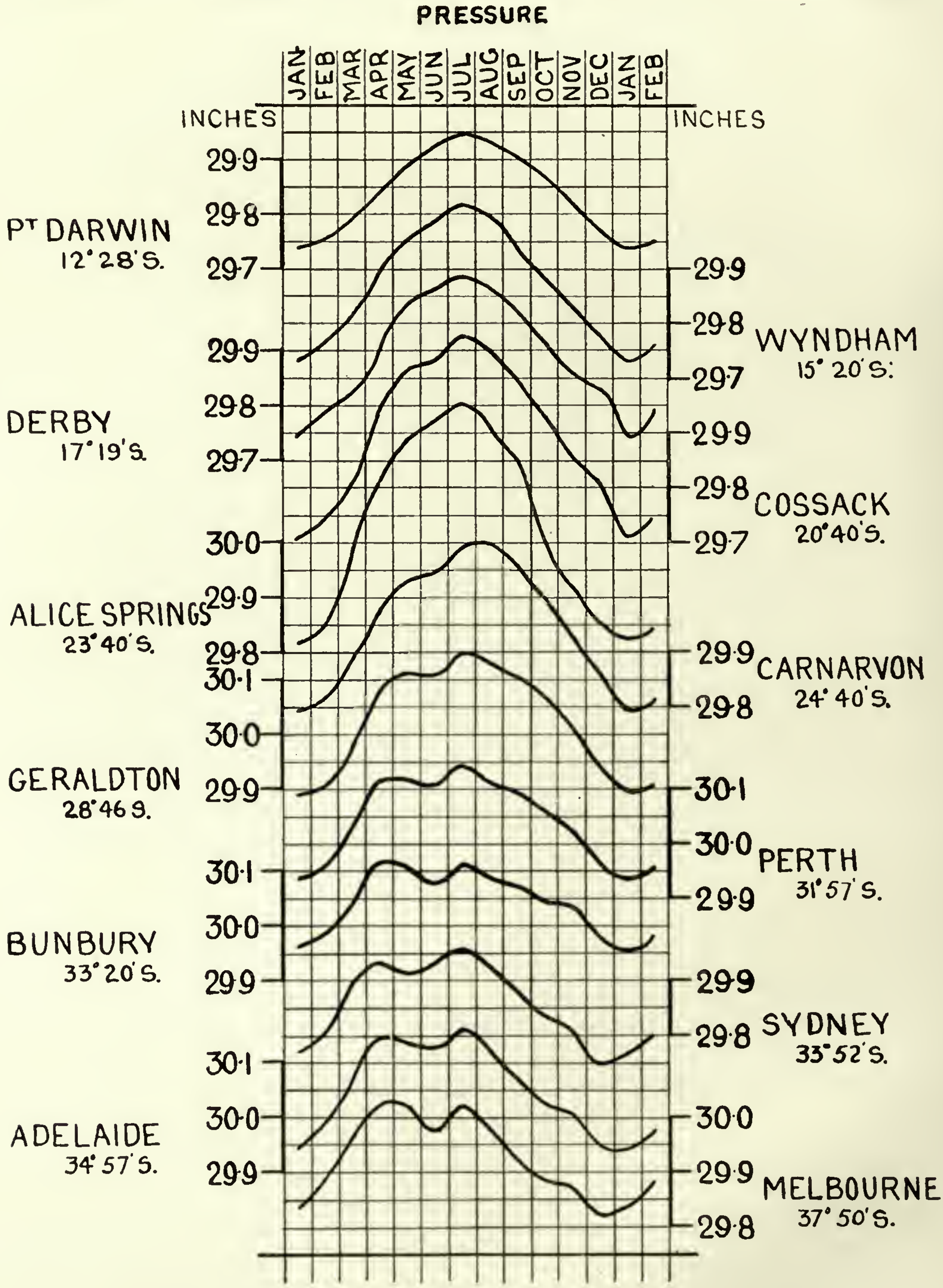


FIG. 4.

course. Any movement in latitude of the low-pressure region under the sun must, therefore, influence the positions, also in latitude, of the anticyclonic areas to the southward of it.

In the course of a year the sun has its greatest northern declination on June 21 and its greatest southern declination on December 22. Let us consider for a moment this change of the sun's position in latitude with reference to the annual pressure changes of the lower latitude Australian stations. Taking the Australian midsummer condition first, namely, that when the sun has its greatest southern declination, December 22, the low-pressure region under the sun will have its most southern position, and consequently the anticyclonic region bordering its southern side will likewise be furthest south from the equator. About December, therefore, the stations in North Australia should indicate their lowest seasonal pressure, as at this time they are nearest the centre of the low-pressure region and furthest from the centre of the anticyclonic area. As a matter of fact, the pressure curves indicate their lowest values in January, or a month late. The delay in the occurrence of the maximum is of the same length.

If now the Australian mid-winter be considered, this epoch being when the sun has his greatest northern latitude, that is, June 21, the low-pressure area under the sun will be in the northern hemisphere. The path of the southern anticyclones will now lie in lower southern latitudes, *i.e.*, nearer the equator. At this season of the year stations in North Australia will be nearer the centre of the anticyclones and furthest away from the low-pressure area under the sun, so that in this month they should indicate their highest pressure during the year. The month of highest pressure for these stations is July, that is, a month late, or a similar lag to that of the lowest pressure.

Turning attention now to the mean annual pressure curves of Australian stations in higher latitudes, these show maxima during a year in April and July and a principal minimum in December and January.

It has been shown above that in December the sun has its greatest southern declination and that the low-pressure region under it reaches the northern part of Australia, while the centres of the anticyclones pass along from west to east, skirting the southern shore of the continent. About this time the whole of Australia is undergoing a period of relative low barometer.

As the sun begins to decrease his southern declination and the track of the centres of the anticyclones consequently moves to lower latitudes, all places in Australia experience a rapid rise in pressure. When the month of April is reached the mean position of the centre of the anticyclonic track is about latitude 28° S., and all places have up to then been increasing their mean monthly values of pressure. From April, places in lower latitudes than 28° S. will continue to show an increase of pressure because the centre of the anticyclonic area is still advancing towards them, but those in higher latitudes will display a decrease because they are now to the southwards of the track of the centres of the high-pressure areas which is retreating from them. The southern Australian stations

will therefore indicate a maximum when the centre of the anticyclonic track is over them.

Up to the time of the Australian mid-winter on June 21, when the sun has his greatest northern declination, the centre of the anticyclonic belt moves still more towards the equator, raising the mean monthly pressure of all the northern stations. During this period the anticyclones become much larger in dimensions so that the belt becomes very much more extensive, spreading out more both northwards and southwards, and influencing the pressure in the southern stations to such an extent that a secondary maximum is formed in the curves of the more southerly stations. This increase in size of the anticyclones during the winter months has been previously drawn attention to on page 13.

The decrease in the northern declination of the sun and the consequent retreat of the centre of the anticyclonic belt to higher southern latitudes, should now cause the pressure at all the stations, of lower latitude than the centre of this belt, to fall. Those stations to the southward of the centre of the belt should show a rise in their pressure curves as the centre of the belt approaches them, a maximum being reached in about September to October. At the same time as this rise should occur, the anticyclones are taking on their summer aspect and becoming smaller, so that it is quite possible that this expected rise about September to October may be neutralised. The curves themselves do not indicate this maximum in these months, but at the same time they do not show a rapid descent, but fall gradually and much less gradually than those of the northern stations. In fact, they seem to indicate that the suggestion made above holds good.

So soon as the centre of the track of the high-pressure areas reaches the south coast the pressure curves of all the stations on this continent decrease together.

In consequence of this change of latitude of the track of the anticyclones during the course of a year, it should be expected that, in the southern portion of Australia, the low-pressure wind systems, which travel approximately from west to east, skirting the southern area, should be more prominent in the winter or high-pressure months (April to September) than in the summer or low-pressure months (October to March). On the other hand, the anticyclones ought to be more conspicuous in the summer or low-pressure months (October to March) than in the winter or high-pressure months (April to September).

In order to test this, the individual daily barometric readings of the Adelaide Observatory barometer were carefully examined. These readings were taken from four volumes of the publications of the Meteorological Observations made at the Adelaide Observatory, and covered the period from April 1891 to March 1894. This period was chosen because the mean annual values of pressure for 1891, 1892, and 1893 were very high, average, and very low respectively, and it was

desired to see at the same time whether those different pressure conditions made much variation in the number of anticyclones or cyclones recorded. The method of inquiry was to examine the mean daily readings of the barometer from day to day, and count up for each month the number of passages of high or low pressure systems. Low-pressure systems were sought after first, and when completed the whole series of data was again gone through to pick out the high-pressure systems. A valuable lead was given in the published columns of remarks, as the weather was briefly described there. The following tables, A. and B., sum up the results obtained:—

Table A.

High-pressure Systems.

Months.		1891–2.		1892–3.		1893–4.		Mean.
		No.	Total.	No.	Total.	No.	Total.	
High pressure	April	5	28	7	39	6	29	32
	May	6		6		5		
	June	2		5		3		
	July	6		7		6		
	August	6		8		6		
	September	3		6		3		
Low pressure	October	6	36	9	41	6	35	37
	November	6		7		6		
	December	3		8		8		
	January	6		7		4		
	February	8		5		6		
	March	7		5		5		
	Totals	—	64	—	80	—	64	

Table B.

Low-pressure Systems.

Months.		1891–2.		1892–3.		1893–4.		Mean.
		No.	Total.	No.	Total.	No.	Total.	
High pressure	April	0	5	1	15	2	23	14
	May	0		2		4		
	June	0		2		4		
	July	1		2		3		
	August	3		4		4		
	September	1		4		6		
Low pressure	October	2	3	4	9	3	9	7
	November	0		2		2		
	December	1		1		2		
	January	0		1		0		
	February	0		0		0		
	March	0		1		2		
	Totals	—	8	—	24	—	32	

Now the first results which follow from the above tables are, first, that the anticyclones in Table A. are more numerous in the low-pressure or summer months than they are in the high-pressure or winter months. In all three years examined the same result is obtained, the mean result being 37 for the low-pressure months and 32 for the high-pressure months.

In the case of the cyclones (Table B.) or low-pressure areas, they are more numerous in the high-pressure or winter months than they are in the summer months, the means for the three years being as 14 to 7 respectively. The above results are, therefore, in accordance with what was expected.

From Table B. one can gather also how long, on the average, it takes an anticyclone to pass over a station. It will be seen that during the three years investigated the mean number of anticyclones per year was 69, or nearly six passed over Adelaide during each month. This means that an anticyclone takes about five days to pass over a station.

Mr. Russell, as previously mentioned (page 13), gave the average time of transit as 8·7 days, so that the length of time here determined is considerably shorter than that found by him. There is little doubt that the method of inquiry adopted by him, namely, deductions from a review of weather charts, and that employed here—which was to count the highest daily readings of the barometer —may account for the greater number of anticyclones suggested by the latter method.

A comparison of the Tables A. and B. indicates further very clearly that Australia is dominated by anticyclones, and that low-pressure systems take quite a secondary place.

Chapter IV.

THE MEAN ANNUAL RAINFALL VARIATIONS.

THE MEAN ANNUAL RAINFALL VARIATIONS.

The next step in the inquiry was to find out in which months of the year rain fell in different parts of the Commonwealth.

In looking at a map of Australia on which isohyets are drawn, such as that, for instance, which appears on Plate 26 in Volume III. of Bartholomew's "Physical Atlas (1899),"* it will be seen that the greatest rainfall is at nearly all the coast districts, with the exception of the region adjoining the Great Australian Bight in the south and that in the north-west division. As the inner regions of the continent are approached, the rainfall becomes a rapidly diminishing quantity, until the Great Victorian Desert is reached, where the fall is under 10 inches in the year.

Fig. 3, based on the above-mentioned map, shows at a glance the positions of the isohyets (here dotted) for differences of 5 and 10 inches of rainfall. The isohyet for 5 inches and under has been omitted, as it is not corroborated by more recent data discussed by Mr. Hunt.

Now the rainfall season in the course of a year is not the same for every region of Australia. This fact can be well studied by comparing curves representing the mean annual rainfall variations, and this procedure has been adopted here. Excepting for stations near the coast and those lying on or near the great telegraph line, which passes through the heart of Australia from south to north, rainfall statistics are not numerous. Sufficient data are, however, available to determine the main features of Australian seasonal rainfall.

In order not to deal with curves representing the rainfall of single stations those of areas which exhibit similar variations have been employed in which the values at two, three, or more stations have been combined. Such curves are used as types for those regions.

The following tables give the State, position, number of stations included, years of observation, and seasonal rainfall or annual "rain-beat," reckoning twelve months from the minimum month. In these tables the districts are grouped according as their wettest months occur in the middle of the year, Table A. (winter in Australia), or at the end of the year, Table B. (summer in Australia).

* Bulletin No. 2 (issued July 1908) of the Commonwealth Bureau of Meteorology, Melbourne, by H. A. Hunt, contains a new Rainfall Map of the Commonwealth of Australia.

TABLE A.

State.	Position.	Station.	Years of Observation.	Rain-beat.
West Australia - -	W. (Shark's Bay District).	Geraldton - - -	23	December to January.
		Hamelin Pool - -	14	
		Carnarvon - -	17	
,, ,, -	S.W. (Perth District).	Pinjarrah - - -	23	January to December.
		Newcastle - -	23	
		Bunbury - - -	23	
		Albany - - -	23	
,, ,, - -	S. (Coast).	Esperance - - -	17	December to January.
		Israelite Bay - -	15	
		Eyre - - -	15	
		Eucla - - -	16	
South Australia -	S. (Eyre's Peninsula).	Fowler's Bay - -	23	February to January.
		Streaky Bay -	23	
		Warrow - - -	24	
		Port Lincoln - -	35	
		Warratta Vale - -	24	
,, ,, -	S. (Agric. District).	50 Stations - -	All over 20	February to January.
Victoria - -	—	Bendigo - - -	42	February to January.
		Portland - - -	42	
		Cape Otway - -	40	
		Wilson Promontory -	27	

TABLE B.

State.	Position.	Station.	Years of Observation.	Rain-beat.
West Australia - -	N.W.	Cossack - - -	18	September to August.
		Boodarie - - -	12	
		Condon - - -	12	
,, ,, -	N.	Derby - - -	14	August to July.
		Wyndham - -	13	
South Australia -	N.	Port Darwin - -	31	August to July.
		Daly Waters - -	28	
		River Katherine - -	28	
Queensland - -	N.	Coen - - -	8	August to July.
		Cooktown - - -	8	
		Port Douglas - -	8	
,, - -	S.	Brisbane - - -	14	August to July.
		Rockhampton - -	14	
		Mitchell - - -	8	
,, -	Inland	Hughenden - -	8	July to June.
		Barcaldine - - -	8	
		Boulia - - -	8	
South Australia -	Central	Alice Springs - -	27	August to July.
		Charlotte Waters - -	27	
		Hermannsberg - -	13	
		Tempe Downs - -	13	
,, ,, - -	Lake Eyre District.	Anna Creek - - -	18	July to June.
		Stuart's Creeks - -	24	
		Mulloorina - - -	19	
		Peechawarina - -	19	
		Cowarie - - -	18	
New South Wales -	Inland	Armidale - - -	31	August to July.
		Cassilis - - -	30	
		Tenterfield - -	30	
,, ,, ,, -	Coast	Sydney - - -	38	August to July.
		Port Macquarie - -	30	

The rainfall districts in the above tables are shown for the most part in the accompanying map (Fig. 5) by means of areas surrounded by dotted lines.

In the case of Queensland the districts represented are those later employed for determining the changes of rainfall from one year to another. The mean annual variation rainfall curves in Queensland are, however, so similar with regard to the epochs of maxima and minima that the slight difference between the districts may be neglected.

MAP SHOWING THE RAINFALL STATIONS AND DISTRICTS (INCLUDED IN DOTTED LINES) EMPLOYED.

FIG. 5.

Table 4 (Appendix) gives the mean monthly values of rainfall which have been used in this inquiry.

Curves of these seasonal rainfall beats are reproduced in Figs. 6 and 7; they are all drawn on the same scale, and are numbered according to the key map.

The curves here shown, and they represent the seasonal rainfall for regions widely distributed over Australia, can be divided in the first instance into two main classes, namely, one in which the chief rainy months are in the winter

season (Fig. 6) and the other in which the summer months have the most rain (Fig. 7).

If the map shown in Fig. 5 be consulted, it will be seen that these two classes or types of rainfall can be almost completely separated by a line drawn across Australia extending from the north-west coast about Onslow to the south-east coast about Sydney.

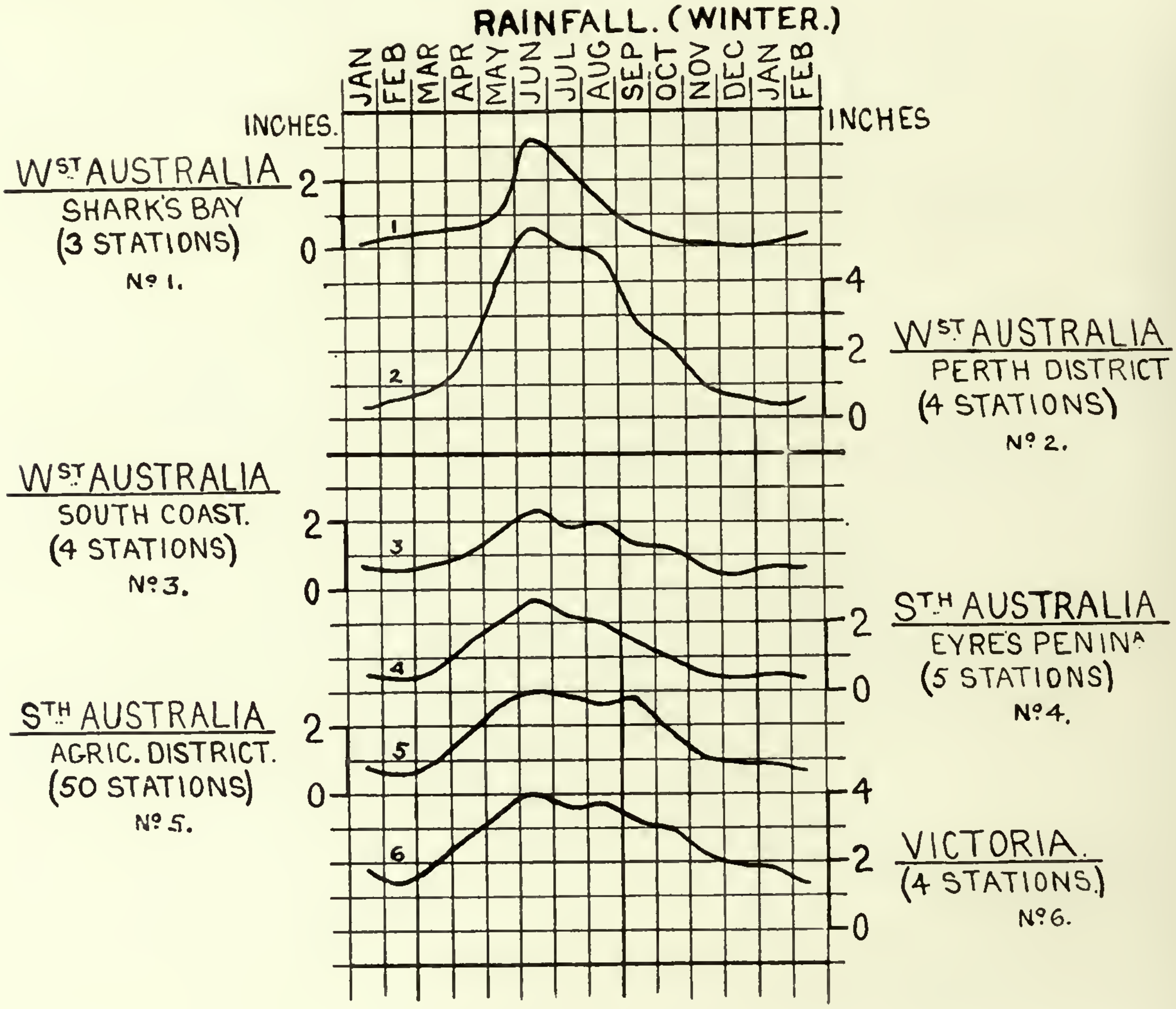


Fig. 6.

Regions neighbouring on this line, such as New South Wales, Lake Eyre District, &c., appear to some extent to be affected by both the rainy seasons, since the curves for these places exhibit two maxima—one about January or February and another about June.

It will be noticed, further, that in both the sets of curves each is divided into two groups by a thick horizontal line. This was done as it was observed that in each main type into which these rainfall curves have here been grouped there were regions in which the minima of the curves sometimes indicated very little or no rain and sometimes quite a considerable amount in relation to the annual amount.

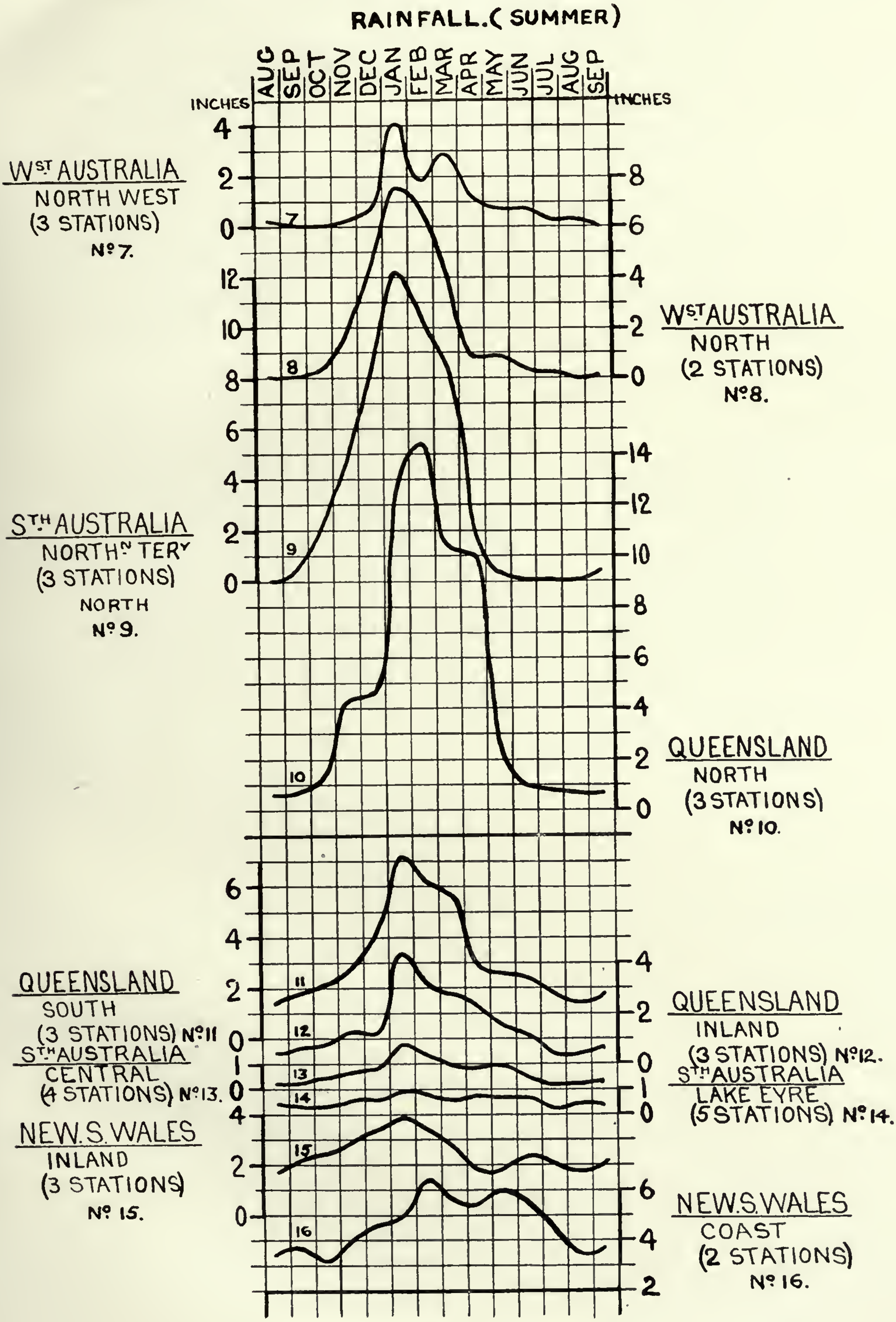

RAINFALL. (SUMMER)
AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
INCHES
INCHES
Wst. AUSTRALIA
NORTH WEST
(3 STATIONS)
No. 7.
Wst. AUSTRALIA
NORTH
(2 STATIONS)
No. 8.
Sth. AUSTRALIA
NORTHn. TERy.
(3 STATIONS)
NORTH
No. 9.
QUEENSLAND
NORTH
(3 STATIONS)
No. 10.
QUEENSLAND
SOUTH
(3 STATIONS) No. 11
Sth. AUSTRALIA
CENTRAL
(4 STATIONS) No. 13.
NEW. S. WALES
INLAND
(3 STATIONS)
No. 15.
QUEENSLAND
INLAND
(3 STATIONS) No. 12.
Sth. AUSTRALIA
LAKE EYRE
(5 STATIONS) No. 14.
NEW. S. WALES
COAST
(2 STATIONS)
No. 16.

Fig. 7.

Thus, to take an example in Fig. 7, the curve representing three stations in the northern territory of South Australia records no rain for the months of June, July, or August, while in the series of curves at the bottom of the figure the minima never reached zero in any month, and in three of the cases the minima indicate a fall of one or two inches.

Somewhat similar remarks apply to the curves in Fig. 6.

Since the curves are all drawn on the same scale, they serve also to show relatively the quantitative distribution of rainfall over the land as previously indicated by isohyets in Fig. 3.

Chapter V.

COMPARISON OF THE MEAN ANNUAL PRESSURE AND RAINFALL VARIATIONS.

THE RELATION BETWEEN THE ANNUAL PRESSURE AND RAINFALL VARIATIONS.

Having now dealt independently in some detail with the curves representing the mean annual variations of pressure and rainfall, it is important next to consider them in relation to each other. The annual barometric change, as pointed out previously, has a maximum in July and a minimum in January. The two main types of rainfall curves have their maxima in July and January respectively.

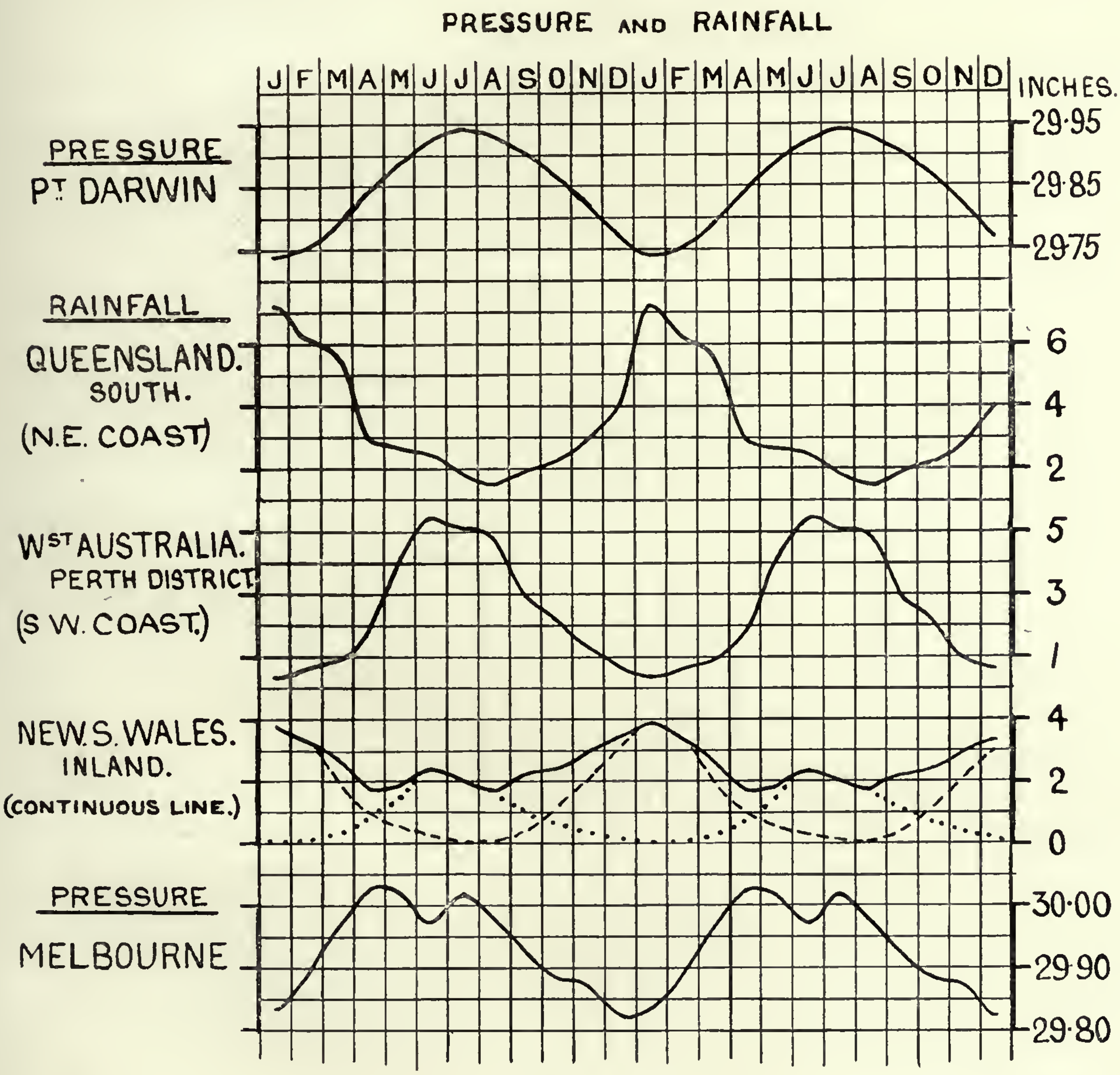


FIG. 8.

One is therefore confronted with the fact that the single annual pressure change is responsible for two quite distinct rainfall pulses.

During the high-pressure months, that is, from April to September, the south and south-west regions of this continent receive their maximum water supply,

while during the low-pressure months the north and north-east regions have their maximum rainfall. This relationship is best seen by looking at Fig. 8, in which the annual pressure curve is compared with the typical rainfall curves of these two regions.

One can quite understand that there must be a region where both these pulses of rainfall should be felt in a year, and this region should be found in a belt the centre of which should pass from about Onslow in the west to about Sydney in the east (*see* page 36).

In the accompanying figure the rainfall curve for New South Wales is given as a type for this double annual pulse of rainfall. To illustrate how this curve appears to be built up, the portions about the points of maximum have been prolonged by dotted lines to correspond with the principal minima of the other two type curves. It will be seen that by adding the ordinates of the two dotted curves together the continuous curve represents very fairly the resulting curve. It will be noticed that the north-eastern type of rainfall affects the rainfall in New South Wales more than that which comes from the west and is represented by the Perth District curve.

The main conclusion to be arrived at from the comparison of these pressure and rainfall curves is that care must be taken to associate the different rain pulses with the pressure changes for the same period. Thus the rain pulse of Queensland, which extends from August to the following July, must be compared with the pressure for the same group of months, while the western rainfall should be compared with the pressure for the months January to December.

Chapter VI.

COMPARISON OF THE PRESSURE AND RAINFALL CHANGES, AND THE FREQUENCY OF "SOUTHERLY BURSTERS" FROM YEAR TO YEAR.

COMPARISON OF THE PRESSURE AND RAINFALL CHANGES FROM YEAR TO YEAR.

It has been shown above (page 9) that the mean annual pressure values for the different stations in Australia are not the same from year to year, but exhibit very similar variations of short duration, lasting for about 3·8 years.

The question now arises, do the rainfall values behave in the same way?

It is proposed here to show that the characteristic rainfall changes are coincident with those found for pressure; the years of lowest mean pressure are those of greatest rainfall over the whole of Australia.

Before making the comparison of these pressure and rainfall values it is as well to point out what is desirable and what is available with regard to the data for such a discussion.

In the case of pressure the readings of one barometer are sufficient to display clearly the changes of the mean value which occur from year to year over a very large area. Thus, in the case of Australia, practically one barometer is required, but a second is desirable as a check on the first.* For rainfall, however, the matter is different To determine the mean annual rainfall for any area the raingauges must be well distributed over it, for the values recorded by any one gauge are subject to variations due to local conditions, such as configuration of district (plain or mountainous), elevation above sea level, &c. In any discussion of rainfall values it is therefore necessary to group together as many stations as possible, each group containing only those records which indicate a similar mean annual variation.

Wet or dry years in Australia are so pronounced in the curves illustrating the variations of rainfall over Australia that it has not been necessary for the present inquiry, which, of course, can only be considered as a first approximation, to group together for each area investigated a great number of rainfall stations. This is very fortunate because, considering the size of the country, raingauges are very scattered, and, further, statistics are not very numerous and they are limited for the most part to the coast areas, and in the majority of cases do not extend over a great number of years.

Nevertheless the material that is available is sufficient, I think, to indicate, at any rate as a first approximation, that a close relationship does exist between the two meteorological elements now in question.

* This statement only applies to the cases where changes occur, the periods of which cover several years. A considerable number of well-distributed barometers is necessary for the daily forecasting work in order to know the positions of the isobars.

It has been pointed out above (page 42) that when considering the relationship between rainfall and pressure, the group of months which include a complete rain-beat, that is, the rainfall from one minimum to the next, should be compared with the mean pressure for the same period.

Thus, for instance, as the rainfall period on the north-east coast extends from August to the following July, the mean pressure for this group of months should only be considered. In the same way, the rain-beat on the south-west coast, which extends from January to December, should be compared with the mean pressure for this period.

Where a region has two rain-beats in twelve months, each should be treated separately and compared with the pressure values for the corresponding periods.

Examination shows that it does not seem necessary always to compare the mean pressure for a *whole* 12 months with that of the rainfall for the same period, but that the pressure for the middle six months of the year can be employed instead. This is due to the fact that the amplitudes of the mean pressure variations from year to year of the middle six months predominate in the variations exhibited by the yearly means.

Thus, instead of comparing the mean pressure for the twelve months January to December with the rainfall for that period, we can employ the pressure for the six months April to September.

Coming now to the actual comparisons of the pressure and rainfall curves themselves, these are shown in the two sets of curves given on Plates 2 and 3. The rainfall data from which the curves are drawn are given in the Appendix (Tables 5 and 6).

To deal with Plate 2 first, here are indicated the winter (April to September) conditions, when the anticyclones reach their most northern latitudes and enable the southern "lows" to give rain to the west, south, and south-eastern parts of Australia. As has been shown in a previous section (page 36), the times of minimum and maximum rainfall during a year for these regions occur in January and June respectively. The rainfall curves here displayed are compared by plotting the total falls recorded during the whole interval of the 12 months, January to the following December, and joining them together consecutively. Each district is treated separately, and, going from west to east, they are as follows :—

Western Australia, Shark's Bay	- - - -	3 stations.
,, ,, Perth District	- - - -	4 ,,
,, ,, South Coast	- - - -	4 ,,
South Australia, Eyre's Peninsula	- - - -	5 ,,
,, ,, Agricultural Districts	- - -	50 ,,
Victoria	- - - - - - - -	4 ,,

Curves representing the rainfall changes from year to year of all the above regions are reproduced in Plate 2 and are drawn on the same scale. The last curve on the plate is that obtained by picking out six stations having about the same mean annual fall, and which are well distributed and included in the above regions.

At the top of the plate, the first curve illustrates the variation from year to year of the mean barometric pressure for the 12 months January to December, and the second curve the barometric variation, also from year to year, of the means for the six months April to September. Both of these curves have been inverted so that their highest points, years of deficient pressure, could be more easily identified with years of excess rainfall.

If the rainfall curves be now compared *inter se* and also with the inverted pressure curves it will be seen that they all indicate in a general way similar variations. It is very probable that the resemblances would be still more striking if it were possible to form rainfall curves based on a greater number of stations in each region, but, as indicated previously, the data are lacking.

The above comparison, considering it as a first approximation only, indicates that, for these regions of Australia, a year with pressure much above the normal corresponds to a year of deficient rainfall, and *vice versâ*.

Turning now to Plate 3, the summer (October to March) conditions are dealt with. It is during this time that the anticyclones pursue a more southern track and the monsoonal "lows" give rain to the northern, north-eastern, and eastern portions of Australia.

In these regions the minimum and maximum months of rainfall are August and January respectively, so that the total rainfall for the 12 months from August to the end of the following July are plotted for each year.

Each district into which this portion of Australia has been divided has, as before, been treated separately, and all the curves have been plotted on the same scale.

The regions dealt with are as follows:—

West Australia, North Coast - - - -	2	stations.
South Australia, Northern Territory - - -	3	,,
Queensland, North-east Coast - - - -	3	,,
South Australia, Northern Territory (Central) - -	3	,,
,, ,, Lake Eyre District - - -	5	,,
New South Wales, Inland - - - - -	3	,,
,, ,, ,, Coast - - - - -	2	,,

Unfortunately, the record available for Queensland is very short. This State was subdivided into four areas, and the rainfall variation for each was determined. As they all indicated changes similar in kind but different in quantity (as was to be expected from coast and inland stations), it was considered sufficient to reproduce only one of the curves.

As before, two inverted pressure curves stand at the head of the plate. The first represents the mean pressure changes, from year to year, for the 12 months August to the following July, while the second shows the mean pressure changes, also from year to year, of the middle six months of this period, namely, November to April. These curves have, as in the preceding case, been inverted.

The rainfall curves have been arranged in order from the top with regard to the general advance of the monsoonal low-pressure area over the northern part of the continent. Thus the northern regions first feel the effect of this low-pressure area, then in order the central and eastern districts, and lastly the south-eastern region.

Comparing now the rainfall curves with those of the inverted pressure curves given at the top of Plate 3, it will be seen that there is a general tendency for the years of greatest rainfall to be coincident with those of lowest pressure (highest points of pressure curves). The coincidences are more striking, perhaps, in the curves of the northern areas, for there the rainfall is solely dependent on the monsoonal "lows," while towards the more central and southern parts the effects of the *southern* "*lows*" are not altogether absent.

The coincidences are, however, sufficiently numerous, and they would probably be more in number if the rainfall statistics represented the facts better, to indicate the close connection between the variations of the winter rainfall and the pressure for that period.

It is unfortunate that the only available data for Queensland extend over the short period of ten years. Nevertheless, for this period high-pressure years are years of reduced rainfall, and *vice versâ*.

Year. August to July.	Pressure. Adelaide.	Rainfall. Queensland, N.E. (3 Stations.)	Rainfall. Queensland. (16 Stations.)
	Inches.	Inches.	Inches.
1896–1897	30·109*	39·57*	20·50*
1897–1898	30·051	65·88	33·44
1898–1899	30·048	52·76	24·43
1899–1900	30·082*	31·73*	18·44*
1900–1901	30·070	49·75	22·38
1901–1902	30·086*	40·27*	12·88*
1902–1903	30·069	69·38	29·68
1903–1904	30·053	62·04	33·80
1904–1905	30·068	44·84	23·07
1905–1906	—	34·30	26·37

The above tabular statement demonstrates this relationship very clearly, the high-pressure years and years of least rainfall being indicated by an asterisk. In column 3 only one district is considered, consisting of three stations in the north-east part of the State. If all the districts be combined, giving a summation of 15 stations, including coast and inland stations, the figures which are shown in the fourth column indicate similar epochs for the minima. No pressure data are yet available for the epoch 1905–1906.

The above comparisons of the variations from year to year of the pressure and rainfall for the winter and summer seasons, suggest what a step in advance would be made if it were possible to predict the pressure even a few months ahead.

The Frequency of "Southerly Bursters."

In the southern portion of Australia, chiefly in the region of Victoria and New South Wales, certain peculiar conditions sometimes occur which give rise to southerly winds of great violence. These storms are known as "Southerly Bursters," as they have the peculiarity of commencing very suddenly; in some years these bursters are much more prevalent than in others.

It seemed of interest to find out whether their occurrence, like that of rainfall, was closely associated with the pressure changes, and whether high-pressure or low-pressure years presented the more favourable conditions for their formation.

The inquiry was very much facilitated, because most of the information required has already been published in an admirable essay on "Southerly Bursters,"* by Mr. Henry A. Hunt, now Commonwealth Meteorologist for Australia, who has brought together and discussed all the available information concerning these peculiar atmospheric disturbances. The period over which the observations he discussed covered, extended from September 1863 to March 1894, about thirty years, so that we have here a valuable series of statistics of bursters recorded at Sydney to deal with. It is hoped that this list will be brought up to date.† Mr. Hunt differentiates between three different kinds of "bursters." The first, the true "southerly burster," is associated with the familiar inverted V depression: and the sharper the V, the more sudden the change. The second type occurs with tropical, or V, depressions, is associated with high temperatures and thunderstorms: this type is of seldom occurrence. The third and last variety results from a secondary. They develop on the south coast of New South Wales through the formation of a "kink" in the outlying isobars of the retreating high pressure.

* "Three Essays on Australian Weather," by Hon. Ralph Abercromby, page 16. [Sydney, 1896.]

† Mr. Hunt has since informed me that the list has been brought up to date, but is not yet published.

The statistics show that bursters are most frequent in the summer months. Thus the totals recorded at Sydney for the period above mentioned are given by Mr. Hunt as follows :—

Month.	Total Number of Bursters.	Mean Pressure. Sydney. (1859–1887.)
		Inches.
August	5	29·927
September	62	·882
October	139	·830
November	166	·807
December	182	·742
January	170	·769
February	132	·801
March	90	·890
April	41	·935
May	4	·913

It will be seen that the month of December has the greatest number, while the months between May and August have only five or less each.

When we compare these figures with the annual variation of pressure at Sydney, the values for which are included in the above table, one is led at first to associate the great frequency of bursters with the low-pressure months. It must be borne in mind, however, that during the low-pressure months the paths of the anticyclones over Australia pursue a more southerly course, barring out to a considerable extent the southerly lows which attempt to wedge themselves in between them. Since the southerly bursters are for the most part met with in Victoria and New South Wales, their frequency is therefore closely associated with the presence of the anticyclones in these higher latitudes. The southerly positions of the anticyclones at this time of the year render the northern portions of a V depression to the south of them very sharp in the region of Victoria and New South Wales. The higher the pressure in the anticyclones the sharper and more intense must the V depression be, otherwise it could not be recorded by the Sydney barometers. One is thus led to conclude that a "southerly burster" is really an attempt of an intense low-pressure system or part of it to wedge itself in between two anticyclones at a time when such a movement is very difficult. There are several other conditions which render this attempt successful, such as those which Mr. Hunt mentions, namely, the flattening of the front of the isobars of the anticyclones against the mountains of New South Wales, the consequent deformation of the V depressions, isobars, &c.

In dealing with the variation in the frequency of bursters from year to year Mr. Hunt gives a very interesting table, which shows that some years are very much more liable to their occurrence than others.

The numbers recorded for each year, reckoning the year from August to the following July, are as follows :—

Year.	Total Number of Bursters.	Pressure. Adelaide.
		Inches.
1863–1864 - - -	31	30·033
1864–1865 - - - - -	36	·071
1865–1866 - - -	37	·065
1866–1867 - - - - -	32 minimum	·044 minimum.
1867–1868 - - -	38	·055
1868–1869 - - - - -	56	·077
1869–1870 - - -	29 minimum	·031
1870–1871 - - - - -	34	·017 } minimum.
1871–1872 - - -	33	·017 }
1872–1873 - - - - -	22 minimum	·071
1873–1874 - - -	30	·059
1874–1875 - - - - -	38	·023 minimum.
1875–1876 - - -	35	·063
1876–1877 - - - - -	37	·101
1877–1878 - - -	32 minimum	·116
1878–1879 - - -	47	·051
1879–1880 - - -	28 minimum	·048 minimum.
1880–1881 - - - - -	37	·099
1881–1882 - - -	33	·060
1882–1883 - - - - -	28 minimum	·059 minimum.
1883–1884 - - -	35	·084
1884–1885 - - - - -	42	·087
1885–1886 - - -	32	·121
1886–1887 - - - - -	20 minimum	·032 minimum.
1887–1888 - - -	32	·095
1888–1889 - - - - -	27	·097
1889–1890 - - -	16 minimum	·045 minimum.
1890–1891 - - - - -	23	·075
1891–1892 - - -	21	·094
1892–1893 - - - - -	21	·007 minimum.
1893–1894 - - -	19	·051

A comparison of the figures representing the different number of bursters and the variation of the barometer from year to year in Australia which has been added in the above table, seems to associate the former with high-pressure conditions.

From the years 1863–1864 to 1869–1870 and from 1879–1880 to 1893–1894 there is a distinct tendency for the years of few bursters to be low-pressure years and years of many bursters to be high-pressure years, and the evidence seems to be very much stronger in the case of the former than the latter.

Thus, prominent low-pressure years, such as 1879–1880, 1882–1883, 1886–1887, 1889–1890, are all coincident with a decreased number of bursters, while the intervening years of excess pressure are conspicuous as years of an increased number of bursters.

Between the years 1870–1871 and 1878–1879 the condition of affairs seems to have been reversed, for the high-pressure years, 1872–1873 and 1877–1878, showed a distinct decrease in the number of bursters, while the low-pressure years, 1870–1871, 1874–1875, and 1878–1879, indicated a marked increase.

From the above inquiry into the variation of the frequency of occurrence of "southerly bursters" there is reason to conclude that years of low pressure are conducive to few bursters and years of high pressure to a greater number.

CHAPTER VII.

HEIGHTS OF THE RIVER MURRAY IN RELATION TO AUSTRALIAN RAINFALL.

HEIGHTS OF THE RIVER MURRAY IN RELATION TO SOUTH AUSTRALIAN RAINFALL.

The Changes in the Height of the River Murray and in the Rainfall of the Catchment Area during a Year.

Introductory.

Having dealt with the rainfall of Australia and indicated the fluctuations which take place from one year to another, it was considered desirable to make an attempt to find out whether the flow of the rivers, or the heights measured by gauges, varied in the same manner. Such a trial could be made only with the River Murray and its tributaries, because in the case of this river the data are very complete and homogeneous for the period over which the observations have been made.

The whole of the river system, which reaches the sea at Wellington under the name of the Murray, is confined for the most part to New South Wales. An important tributary to this river is the Darling, which rises under the name of the Dumaresq in the extreme north-eastern corner of the State, flowing into the Murray at Wentworth. The Rivers Mooni, Culgoa, Warrego, and Parvo, tributaries of the Darling, flow into the State from Queensland, but the others, such as the Guoydir, Namoi, Castlereagh and Macquarie, are confined to New South Wales.

The Murray, the principal river of New South Wales, and indeed of Australia itself, rises in the Snowy Mountains. Before Wentworth is reached it is fed on its northern bank by important tributaries, among which may be mentioned the Lachlan, Murrumbidgee, and Edwards. On the southern bank it has a great number of tributaries which, originating from the Great Dividing Range and the Australian Alps, help to fill its volume very considerably.

The water which the River Murray discharges into the sea may thus be said to be derived from two separate supplies, namely, one, that brought down by the River Darling and its tributaries, and the other, that flowing into the Murray before the Darling joins it at Wentworth.

The accompanying key map (Fig. 9) shows the general configuration of New South Wales and this river system, and also the positions of the river gauges, from which the data here discussed have been obtained.

The Height of the Darling River and Rainfall of Catchment Area.

The step first taken was to find out the relationship between the seasonal rainfall and river flow, because the latter nearly always lags some months behind the former. In a paper published in 1905* Sir Norman Lockyer and I pointed

* Roy. Soc. Proc., A., Vol. 76, page 494. 1905.

out that, in the case of the River Thames, the month of mean minimum flow followed five months after that of mean minimum rainfall. In other words, the mean flow of the Thames was a minimum in August, while the rainfall was at a minimum in March, or five months earlier.

To deal first with the River Darling, the readings of the gauge situated at Bourke were first examined. Monthly means of the height of the river at this

Fig. 9.

point for the period of 23 years were formed and the mean annual variation curve drawn. The mean monthly readings of all the gauges here employed will be found in the Appendix (Table 7). This curve is reproduced in Plate 4, and it will be seen that during a year it shows two maxima in March and August, and two minima in January and May.

Much further down the river, after it has been joined by the Warrego, is situated the Wilcannia gauge. The readings of this have been treated in

precisely a similar manner. The mean annual curve, which is also for a period of 23 years, shows exactly similar variations, the times of maxima and minima corresponding with those of the curve for Bourke.

Treating the gauge records at Pooncarie, a station still further down the Darling, in like manner, another curve showing the same kind of variation is obtained. This curve is, however, a month later in all its phases than those of Wilcannia and Bourke, thus indicating the average time taken for the water to travel from Wilcannia to Pooncarie.

These three river curves suggest therefore very distinctly that the rainfall of the catchment area has a double annual beat, or, in other words, two maxima in a year.

Looking at the key map (Fig. 9) showing the river system of the Murray, it will be seen that the catchment area of the Darling includes a portion of South Queensland and more especially the inland region of New South Wales. In a previous part of this memoir (page 37) the mean annual rainfall variations for these regions have been given, and it was shown that while the annual curve for Queensland displayed only one maximum in the year (in January), that of New South Wales showed a distinct double beat with maxima in January and June.

The typical rainfall curves for these two areas are again reproduced in Plate 4, and they are compared with the curves of the two gauges at Bourke and Wilcannia. The first obvious conclusion to be drawn is that the river-height variations resemble more closely the seasonal rainfall of New South Wales than that of South Queensland. Such a result is quite in harmony with expectations, considering the great number of tributaries which drain the New South Wales area.

The next point to be noticed is that the two maxima, in January and June, in the rainfall curve of New South Wales are followed in each case two months later by the maxima of the river curves. In other words, the River Darling has a lag of two months on the rainfall, if the maxima points are alone considered.

As, however, it is desirable, in treating of the changes in rainfall and river from year to year, to associate the seasonal rainfall with its corresponding seasonal river height, the grouping of the months had to be different in each case.

Thus, if the seasonal rainfall of New South Wales be considered as occurring between August and the following July, both months inclusive, then the corresponding river-height seasonal variation should be taken as being included in 12 months between the January following the August mentioned above and the succeeding December.

This part of the subject will be considered in a later paragraph when the other branch of the River Murray has been dealt with.

The Height of the Murray River above where it is joined by the Darling, and the Rainfall of the Catchment Area.

Directing our attention to the River Murray just before it is joined by the Darling, the heights recorded at three well-distributed gauges have been examined. The first of these is at Moama, well up the river, but just below the point where the Goulburn river joins it. The second, Balranald, is below the junction of the Lachlan with the Murrumbidgee, but above where these rivers join the Murray. Euston, the third gauge, is on the Murray, above the junction of this river with the Darling.

Treating the data giving the heights of these rivers in a similar way to those of the Darling gauges, mean annual curves, the data for which are in the Appendix (Table 7), were drawn and are reproduced in Plate 4. All the curves show a minimum value in March, while the maximum occurs in September for Moama and October for Balranald and Euston. These curves are thus quite different from those given by the Darling gauges.

The catchment area of the Murray, above where it is joined by the Darling, may be said to be divided into two parts. The Murrumbidgee and Lachlan derive their water supply from New South Wales, but the Murray, above where these tributaries join it, drains Victoria.

The curves representing the typical variations of the seasonal rainfall of these two areas are reproduced in the same Plate, together with the mean annual variation of the heights of three gauges mentioned above.

It will be seen by comparing the curves together that the variation of this part of the River Murray is more associated with the rainfall of Victoria than that of New South Wales, for it is restricted mainly to a curve having one and not two maxima. The curve again lags behind that of the rainfall, there being a difference of about four months in the case of the epoch of maximum for Balranald and Euston and three months for Moama. The river height at minimum follows a month after that of rainfall.

In dealing, therefore, with the changes from year to year, in this case also the rainfall must be compared with the corresponding seasonal river height. Thus the rainfall for the twelve months February to January should be compared with the river heights for the period April to March.

The Height of the Murray where the Darling joins it.

We see from the above analysis that the height of the River Darling has a variation showing two maxima in the year corresponding to the rainfall in the New South Wales catchment area, while the River Murray above Wentworth has one maximum during the year closely associated with the rainfall variation of the Victoria catchment area. Since the volume of the River Murray above the point where the Darling joins it is so very much greater than that of the Darling

itself, it was to be expected that the mean annual variation of the gauge readings at Wentworth, where the Darling and Murray unite, would present features more similar to the gauge at Euston than that at Wilcannia. Curiously enough, the curve of the seasonal variation of the Wentworth gauge shows no trace of the double maximum so prominent in the Darling gauges, but is very similar both as regards epochs of maximum and minimum with the curves of the Euston and Balranald gauges. A comparison of all these gauges is given in Plate 4, and the difference, to which mention has just been made, will be seen at once.

The fact that the Darling variation is not reproduced in the Wentworth gauge is of considerable importance, because a similar conclusion is independently drawn when dealing with the changes of the heights of these gauges from year to year; reference to this point will be made in a subsequent paragraph (page 61).

The Changes in the Height of the River Murray and in the Rainfall of the Catchment Area from Year to Year.

The Darling Gauges and Rainfall.

Leaving now the subject of the annual variation of the heights of the different river gauges, and turning attention to the changes of height from one year to another, the data employed above have to be treated differently. It has been pointed out previously that, in dealing with seasonal rainfall (page 33), the total fall for the season should be that included in the interval between one minimum month and the next. Thus, in the case of South Queensland, the seasonal rain-beat occurs between August and the following July. For Victoria, the rain-beat is from February to the following January, while in the case of New South Wales (inland) the double beat of rainfall (or the triple beat, as in the case of the stations near the tributaries of the Murray) may be taken as being included between August and the following July.

As the river-flow lags behind the rainfall, the minima of the curves indicating the river height follow those of rainfall. For accurate correlation purposes it is therefore necessary to compare the rainfall for one set of months with the mean height of the river gauges for another set.

The actual cases under consideration are all brought together in the form of curves in Plate 5, and the following table shows the groups of months employed in each case:—

Rainfall.	New South Wales	August to July.
Height of river.	Bourke	January to December.
,, ,, ,,	Wilcannia	,, ,, ,,
,, ,, ,,	Moama	April to March.
,, ,, ,,	Balranald	,, ,, ,,
,, ,, ,,	Euston	,, ,, ,,
,, ,, ,,	Wentworth	,, ,, ,,
Rainfall.	Victoria	February to January.

The mean readings of the above gauges are brought together in Table 8 in the Appendix.

Dealing first with the Darling gauges, the curves of which are shown in Plate 5 (curves second and third), it will be seen that the changes in the seasonal heights from year to year are very similar in both curves.

In order to compare these changes with those of the seasonal rainfall from year to year in New South Wales, each mean gauge value is placed vertically beneath the corresponding rainfall value. Thus the mean value of the river gauge at Bourke for the period January to December 1887 is placed below the point in the New South Wales rainfall curve, which represents the fall between August 1886 and July 1887. The very close association between all three curves indicates clearly that the river variations from year to year corroborate the rainfall changes.

Attention must, however, be drawn to the exceptional value of both the gauges for the year 1886, as this has no apparent equivalent in the rainfall for New South Wales for the period August 1885 to July 1886, which period should correspond to that of the river height. This point is referred to in a subsequent paragraph.

The Murray Gauges above the Junction with the Darling, and the Rainfall.

Treating in a similar manner the gauges on the river system of the Murray, above where the Darling adjoins it, the three curves in Plate 5 indicate the variations in the heights at Moama, Balranald, and Euston. The values for each seasonal height are the mean heights for the group of months April to the following March, and correspond to the seasonal flow of the Darling for the months January to December, as indicated by the Bourke and Wilcannia gauges.

Thus a point on the Moama curve representing the mean height of the river for the months April 1887 to March 1888, is placed vertically under the mean height of the Wilcannia gauge for the period January to December 1887.

The first point that will be noticed when comparing these three Murray gauges among themselves is their great similarity. They all show practically similar changes, indicating the effect of one general cause acting over this area. Further, these curves have practically the same features as those of the Darling gauges. There is, however, one point of exceptional difference, and that is, that the high values for the gauge readings on the Darling for the group of months January to December 1886 have no counterpart in the Murray gauges for the corresponding period April 1886 to March 1887. This difference was remarked by Russell in the volume entitled "The Results of Rain and River Observations made in New South Wales, 1886" (page 10), in which it is stated:—

"The Murray river during 1886 was remarkably low until August, when a moderate flood began. The earlier rains in May, which produced such a consider-

able flood in the Darling, produced no effect upon the Murray, a clear proof of the limitation of those rains."

The Gauge at Wentworth, the Junction of the Murray with the Darling.

Glancing now at the key map (Fig. 9) showing the whole of the Murray river system, it will be observed that the position of the gauge at Wentworth is such that it records the height of the River Murray where the Darling joins the main stream.

Treating now the mean values of the gauge values at Wentworth, each value representing the mean height for the group of months April to the following March, the curve showing the variation from one year to another was formed and is displayed near the bottom of the Plate 5.

A comparison of this curve with the two sets of gauge curves representing the variations of the Darling and the Murray before it joins that river, shows in the first instance that the variations of the Wentworth gauge are nearly exact counterparts of those of the Murray.

The same remark would nearly apply in the case of the Darling gauge variations if it were not for the striking exception for the year 1886. During that year both the gauges on the Darling indicate a large mean depth, while all the gauges on the tributaries of the Murray above its junction with the Darling and on the Murray itself, even at Wentworth, show no sign of a high value.

This suggests that the variations of the River Darling do not play so great a rôle in effecting the height of the gauge at Wentworth as the Murray itself above where the Darling joins it. This secondary position of the Darling is in harmony with a similar conclusion previously drawn (page 59), where it was shown that the two maxima in the annual variation of the height of the Darling were absent from the annual variation curve of the Wentworth gauge. The month of the maximum (October) of the Wentworth gauge corresponded, on the other hand, closely with those of the gauges on the Murray, all of which indicate October as the month of greatest height.

From the above treatment of the variations of the heights of the gauge readings recorded on the Darling and Murray rivers one is led to conclude that the observations of the rivers bring out changes from year to year which are in harmony with the rainfall and pressure changes which have been discussed in previous chapters.

Chapter VIII.

BAROMETRIC AND RAINFALL CHANGES OF LONG DURATION.

BAROMETRIC CHANGES OF LONG DURATION AND CORRESPONDING RAINFALL VARIATIONS.

In a previous part of this memoir it has been shown that the barometric variations over Australia undergo changes of short duration, the period of which is about four years. Underlying these changes are very apparent fluctuations of much longer duration, which have undoubtedly to be taken into account in consequence of their magnitude. Such changes have previously been drawn attention to by me in a communication to the Royal Society,* but they will again be referred to here in order to make this memoir more complete.

Fortunately, three excellent series of barometric observations are available for this region, namely, those for Adelaide, Melbourne, and Sydney, commencing respectively in the years 1857, 1859, and 1858. The changes at Perth are also included here, as there is a set of observations commencing in 1876, which will represent the variations which take place well to the west of Australia.

The first step taken to render more apparent the changes of long duration involved in all these curves was to eliminate as far as possible the prominent short variations of about four years' duration. This was to a great extent accomplished by grouping the years in sets of four and employing the mean values of each of these groups. Thus the means for the years 1873 to 1876, 1874 to 1877, 1875 to 1878, and so on, were determined, and curves were drawn through each of these points after they had been plotted. Each mean value was actually plotted on the time scale at the end of the second year of the group of which it was the mean. Thus the mean for 1873 to 1876 was plotted at the end of 1874.

The curves for the four stations are reproduced on the same scale in Plate 6, and their monthly, annual, and four-year mean values are given in Table 2 in the Appendix.

The prominent features of the curves are as follows:—

About the year 1867 and 1868 three of the curves, the records of which go back to this date, indicate a prominent maximum.

About the year 1878 three of the curves, namely, Melbourne, Sydney, and Perth, show a small subsidiary maximum, while that in the case of Adelaide is more pronounced.

About 1887 all the curves indicate a large maximum, greater than any of those that preceded it.

About 1896 another subsidiary maximum seems to be indicated, and it looks as if the curves are tending towards a prominent maximum about 1906.

* Roy. Soc. Proc., A., Vol. 78, 1906, page 43.

If for a moment the curve for Adelaide at the epoch 1878 be left out of consideration it will be seen that the curves bear a close resemblance to one another.

An hypothetical curve embodying the main features of these changes has been drawn at the bottom of the set of curves. This is intended to indicate in one curve the general nature of the variations as regards their epochs of maximum and minimum.

The epochs of the two principal maxima are seen to occur at about 1868 and 1887, while three subsidiary maxima are suggested about the years 1859(?), 1878, and 1897, but the epoch of the first of these is uncertain, as the curves do not extend over a sufficiently long period of time. Nevertheless it may be remarked that the interval between the two chief maxima is 19 years, while those between the successive secondary maxima are about the same length.

In the hypothetical curve those portions representing the fall from and the rise to the principal maxima have been connected by a dotted line as if a subsidiary maximum did not exist, thus forming a principal (but really non-existent) minimum.

From this it is suggested that the curve rises quicker than it falls, the interval being eight years for the former and eleven years for the latter.

The Magnitude of the Pressure Change of Long Duration.

In order to determine the amplitudes of pressure variations of long duration the difference between the readings of the several maxima and minima of the curves plotted were determined.

For the three stations Adelaide, Melbourne, and Sydney the differences for each were 0·054, 0·043, and 0·058 inches respectively, the means of them being 0·052 inches.

The actual values from which the above figures were derived are stated in tabular form below, and it must be remembered that as the points on the curve are derived from means of four years, the years given refer to the two middle years of each four:—

Adelaide.

Year.	Inches.	Mean.
	Minima.	
1861–62	30·023	
1870–71	33·035	30·029
	Maxima.	
1877–78	30·082	
1886-87	30·093	
1895–96	30·073	30·083
Difference	—	0·054

Melbourne.

Year.	Inches.	Mean.
	Minima.	
1862–63	29·914	
1873–74	29·921	
1893-94	29·915	29·917
	Maxima.	
1867–68	29·947	
1886–87	29·973	29·960
Difference	—	0·043

Sydney.

Year.	Inches.	Mean.
	Minima.	
1862–63	29·842	
1874–75	29·829	
1880–81	29·837	29·836
	Maxima.	
1857–58	29·896	
1886-87	29·902	
1895–96	29·883	29·894
Difference	—	0·058

The mean difference for the three stations, taken together, is 0·052 inches.

The Relation between the Pressure and Rainfall.

It has been previously shown (page 48) in the case of the pressure and rainfall changes of short duration that in a year of excess or deficient pressure the rainfall over the whole of Australia was deficient or in excess respectively. It was expected, therefore, that a similar relationship would hold good in the case of the changes extending over several years.

For this purpose a search was made to secure the longest homogeneous series of rainfall data. Unfortunately, such records are not very numerous, and it was only found possible to examine the data for Sydney, Brisbane, Adelaide, Yanko, Melbourne, Perth, and a summary of stations representing the agricultural districts of South Australia.

In order to eliminate the variation of short duration (four years) prominent in all the curves, four-year means were utilised as was done in the case of pressures. By this method the variation of long duration becomes more conspicuous, although the curves are still not very smooth.

The separate curves thus obtained are reproduced in Plate 7, and for purposes of comparison the four-year mean pressure curve (inverted) for Sydney and the inverted hypothetical barometric curve are also added.

The annual and four-year mean rainfall values employed above are given in the Appendix (Table 9).

Although the agreement between the rainfall curves is not as good as one would have desired, especially during the years 1840 to 1860, when the Sydney and Adelaide curves are the inverse of each other, yet they all show that nearly a similar rainfall change of long duration is in existence, and that it is associated (with the exception of the epoch above mentioned) with the pressure variation of about the same period.

On the suggestion of Mr. Hunt, the rainfall data for Horsham were also dealt with, and the curve obtained (but not here shown) was found to indicate similar epochs of maxima and minima to the curves given in the plate. The data on which the curve was based will be found given in the Appendix (Table 9).

So far as the data of pressure and rainfall permit, one is thus led to deduce that there is a variation of about 19 years period in both these meteorological elements.

The long *barometric* swing of 19 years in Australia does not seem to have been pointed out before (Brückner omitted the Australian area in his pressure investigation),* but the existence of a 19-year period of rainfall change has often been mentioned.

* "Klimaschwankungen seit 1700," Eduard Brückner, page 194. 1890.

In an article on the "Development of Meteorology in Australia," by Mr. Andrew Noble, of the Sydney Observatory, it is stated: "Australian meteorology "is greatly indebted to the Rev. W. B. Clarke for his untiring efforts in its "behalf during those early years, beginning with his observations at Paramatta "in the year 1839 and continuing long after the inauguration of the New South "Wales service under Government auspices in the year 1858. . . . The "19-year cycle theory, elaborated by Mr. Russell in more recent years, was "advanced by Mr. Clarke in the 'Sydney Morning Herald' of May 1, 1846."* This reference is of great interest, since it indicates that this 19-year variation was evidently quite a prominent feature of Australian weather *before the observations* discussed in the present memoir were made.

In "Notes on the Climate of New South Wales," 1870, Mr. H. C. Russell advocated a 19-year rainfall change, and in a later paper, which he published in 1876,† he more strongly advocated this rainfall cycle.

In a still later paper, which he published in 1896,‡ Mr. Russell collected information of a miscellaneous kind and extended his 19-year rainfall cycle both over a greater period of time and a wider area. In fact, Australia, India, Europe, Asia, Africa, North and South America, all tended to give him general ideas relating to droughts, which he marshalled, and from which he deduced that this cycle was occurring over the whole earth, epoch for epoch, nearly simultaneously.

With this latter conclusion I cannot, however, agree, for research of late years has shown that while practically one half of the world is undergoing excess pressure the other half is experiencing diminishing pressure. In consequence of this pressure variation the rainfall must and does follow suit, so that where the pressure is in excess the rainfall is in deficit, and *vice versâ*. Thus, a drought cannot occur over the *whole* world simultaneously, although it may extend over a considerable portion of the globe at one time, such as over East and South Africa, Arabia, India, East Indies, and Australia. A drought over this area would probably correspond simultaneously to an excess of rainfall over North-west Africa, North and South America, and Siberia, for in those regions the pressure at that time would be deficient.

* "Monthly Weather Review," Vol. 33, No. 11, November 1905, page 489. [Washington, U.S.A., Weather Bureau.]

† "Journal of the Royal Society of New South Wales," Vol. 10, page 151. 1876.

‡ "Journal of the Royal Society of New South Wales," Vol. 30, page 70. 1896.

Chapter IX.

THE RELATION OF AUSTRALIAN PRESSURE CHANGES TO VARIATIONS IN OTHER PARTS OF THE WORLD.

THE RELATION OF THE AUSTRALIAN PRESSURE CHANGES TO VARIATIONS IN OTHER PARTS OF THE WORLD.

The Variations of Short Duration (about 4 Years.)

In the preceding chapters it has been shown that the pressure over Australia from year to year undergoes two variations, one indicating a variation which takes about four years to complete a cycle, and the other a cycle which seems to be about 19 years in length.

It has also been shown that these two variations are not solely restricted to Australia, but that they are very intimately associated with changes that occur in other parts of the world.

In dealing, therefore, with the meteorology of Australia it is fundamental that a careful watch should be kept on the changes taking place elsewhere, and by so doing it is quite possible that in time to come the key to long-period forecasting, that is, the prediction of the nature of seasons, will be based on such broad views as are above indicated.

It is proposed, therefore, in this chapter to indicate briefly the probable association of Australian pressure changes with those taking place in India, South America, and South Africa.

In a previous part of this memoir reference has been made to a world-wide barometric see-saw which has recently been discovered by the comparison of pressure changes from year to year at a great number of stations well distributed over the earth's surface. So far as could be made out, the two centres of these inverse pressure types were situated, one in South America (about Cordoba), and the other in India, with Bombay as the type.

The presence of this see-saw indicated distinctly that in some years there seemed to be a cause in operation which produced over the South American region a higher pressure than usual, while *at the same time* there was a deficiency of pressure over the Indian area, and *vice versâ*.

This transference of pressure, from approximately west to east and east to west, was found to have a period of about 3·8 years in the mean.

The result of the discussion of the pressure changes indicated that the South American type of variation was closely associated with the changes going on in the United States, Central America, North-west Africa, Siberia, and Honolulu.

The Indian type, on the other hand, was intimately associated with the variations taking place in Europe, North-east and South Africa, Arabia, East Indies, and Australia.

In the study, therefore, of Australian meteorology the pressure changes of Batavia (East Indies), Bombay, and Cape Town should at least be kept well in view, and all of these should be carefully compared with the reverse pressure changes which occur simultaneously at Cordoba.

To indicate the nature of these barometric variations in widely separated stations, attention may here be drawn to the changes which occur from year to year in the regions of South America, South Africa, India, East Indies, and Australia. Not only are these changes very prominent in the annual values of pressure which have been used, but they are equally conspicuous in the group of the six months April to September.

Plate 8 shows two curves for each of these stations, displaying the changes in the yearly and six-monthly values in the upper and lower set respectively. The values that have here been utilised will be found brought together in the Appendix (Table 10).

Taking the curves formed by employing the annual values in the first instance, the pressure changes for Adelaide are placed near the middle. Below this the curves for Batavia (East Indies) and Bombay are given, and they are seen to be very similar to that of Adelaide. This shows that the whole of this region is undergoing changes from year to year which may be said to be common to them all. Towards the upper portion of the plate the pressure curves for Cape Town (South Africa) and Cordoba (South America) are added for comparison. While the Cordoba curve is nearly the inverse of Adelaide, that is, years of high pressure in South America are simultaneously years of low pressure in Australia, the curve for the Cape seems to be intermediate, being more inclined to be similar to the Australian type of variation than that of South America.

It was at first suspected that these pressure changes from year to year were caused by a wave of high pressure travelling round the earth from west to east, and the intermediate nature of the Cape curve in relation to those of Cordoba and Adelaide tended rather to further this view. It was found, however, that the pressure change was more probably caused by a see-saw movement from west to east and east to west alternately, because the stations intermediate between South America and India did not on the whole exhibit the same kind of variation as Cordoba with a time-difference of phase, but a variation of a different type.

The curves in the plate mentioned above demonstrate very clearly the close inter-relationship between pressure changes occurring in widely separated regions, and this association holds good even when the pressure for the groups of six months April to September is only taken into account. A comparison of these six-monthly pressure values is given in the lower half of the same plate. The study of the inter-relationship of these pressure changes is therefore of extreme importance for Australian meteorology, but a great amount of research work is still needed before the variations can be accurately interpreted.

Variations of Long Duration.

While the above remarks have reference only to the pressure changes of short duration, such as that which covers about 3·8 years, the barometric variation of about 19 years duration must not be ignored; in fact, it seems to be a very important factor in Australian weather changes.

Reference has already (page 67) been made to these changes of long duration, both as regards pressure and rainfall, showing that the maxima of the curves are separated by an interval of about 19 years. In South America, changes covering a similar length of time, but with different epochs of maxima and minima, are also in operation, and these have recently formed a subject for a communication by me to the Royal Society.*

Unfortunately, the barometric data for South America are not very numerous, but utilising those that were available, four-year mean curves, formed in a similar way to those obtained for the Australian stations, were drawn. The stations employed were Cordoba, Goya, and San Juan (Argentine Republic), Santiago (Chili), and Curityba (Brazil). Although the curves extend over different periods of time, there is sufficient overlapping in all cases to connect up one series with another.

The Cordoba curve undoubtedly indicated that a long barometric change was taking place, but the shortness of the period over which the observations extended, namely, from 1873 to 1904, rendered it unserviceable for the determination of its possible periodicity. A neighbouring station, Goya, corroborated in a general manner, so far as the observations extended, the Cordoba variation, with perhaps the exception of the first three points on the curve.

To carry back the pressure changes to an earlier date, the observations at San Juan (Buenos Ayres) were employed; the available data for this station extended from 1867 to 1889. Here the fall of pressure at Cordoba from 1875 to 1882 was well corroborated, followed by a subsidiary maximum similar to that at Goya in 1885. So far as these observations extend, there seemed to be two prominent maxima at about the epochs 1874 and 1893, which were followed by minima at about the years 1882 and 1901 respectively.

The curve for Santiago, a station to the west of the Andes, indicated also very clearly these two principal maxima and the second of the two minima at the same epochs, but the minimum about the year 1882 occurred somewhat earlier. At a station in Brazil, Curityba, in which only a short series of observations was available, this long variation is also in existence; the second principal maximum, however, fell a little later than at the previously mentioned stations.

Forming a hypothetical curve in exactly the same way for the South American region as was done in the case of Australia (*see* Plate 6), the two

* Roy. Soc. Proc., A., Vol. 78. 1906.

principal maxima fall in the years 1874 and 1893, while a subsidiary maximum occurs somewhere between 1880 and 1885. Here again the interval between the two main maxima is 19 years. This curve is reproduced in Plate 9, and below it is given the Australian curve for comparison.

In both of the hypothetical curves those portions representing the fall from and the rise to a principal maximum have been connected by a dotted line as if a subsidiary maximum did not exist.

The object of doing this is to indicate that in the Australian area the rise to the principal maxima seems to be more abrupt than the fall from them, while in the South American area *the opposite* features seems to be the case. An unsymmetrical curve seemed in both cases to represent the main features better than one drawn symmetrically. In fact, in the Australian area there is suggested an 8-year rise and an 11-year fall, while in the South American region an 11-year rise and an 8-year fall is indicated.

Particular attention is called to this unsymmetrical peculiarity of the curves, since a similar feature was found to be present in the curve representing the barometric variation of about four years duration,* in operation in India and Cordoba. It was there stated that for Cordoba "the points of maxima of the " hypothetical curve at the top of the plate do not lie midway between the " minima on either side of them, but nearer the preceding minimum."

The first striking fact which this comparison indicates is the remarkable similarity of the nature of the variation in the two cases. Both curves seem to have principal maxima occurring at intervals of about 19 years, while situated between these is another maximum of a subsidiary nature.

The second point of importance is that the epochs of these maxima in these two areas *are not coincident.* Further, we are not here in the presence of a barometric see-saw, or opposite pressure variation, because the Australian maxima do not occur simultaneously with the South American minima; there seems to be a general time-difference of phase amounting to about six years, the epochs of the Australian high pressures preceding those of the South American region.

In the case of the barometric variations of *short duration* existing between India and South America, the inversion of the latter curve corresponded exactly with the direct curve of the former. In order to make a similar comparison, the South American curve, representing the curve of long duration, has here also been inverted, and it will be observed that on Plate 9 the curves are not quite the inverse of each other.

It is unfortunate that the length of time, covered by the observations discussed above, is not sufficient to determine whether these variations of long duration are periodic or not; the curves, so far as they go, suggest that distinct changes of long duration are in operation.

* Roy. Soc. Proc., A., Vol. 76, page 503, 1905, note.

Whether the difference of phase between the South American and Australian pressure curves will in the future be a means of forecasting Australian weather cannot be stated, but the curves are so suggestive that if future observations give further indications of this apparent periodicity, an attempt might be made.

The examination of the Australian and South American pressure observations for variations of long duration and the interesting conclusions derived, suggested an inquiry into the nature of the changes occurring in South Africa and India.

The variations of long duration occurring in the Indian area have already been discussed by me in a previous publication,* so only a brief reference will here be made to them.

By forming four-year means of the Indian pressure values (*see* Appendix, Table 10) fairly smooth curves were obtained for several stations. These curves were seen to be exactly alike, indicating that the origin of the variation was general to all Indian stations. One of these curves, namely, that for Bombay, is reproduced in Plate 10 and shows the nature of the variation which was found.

As a stepping stone to the Australian area the observations made at Batavia, Java, in the East Indies, were similarly treated (*see* Appendix, Table 10). Although the observations do not extend over such a long series of years, yet where the curve overlaps that of Bombay it will be seen (Plate 10) that they present striking similarities, suggesting a common origin.

Coming now to the Australian continent, curves for four stations having already been reproduced in Plate 6, I have previously pointed out that the variation exhibited by the Adelaide curve differed from those of Melbourne, Sydney, and Perth. This I did in the following words† :—

"It will be seen in the first instance that the Adelaide curve resembles in a general way that of Bombay and that the maximum about the years 1877 and 1878 in India is almost equally pronounced in Adelaide. Attention is specially drawn to this particular maximum, as it will be observed when examining the curves for Melbourne, Sydney, and Perth, that during these years it becomes of quite secondary importance."

The above statement indicates, therefore, that while the Adelaide curve bears a family likeness to the other three stations on the same continent, yet it shows a stronger resemblance to the Indian and Batavian curves. In Plate 10 the curves for Adelaide and Sydney have been reproduced again in order that they can be directly compared with the curves representing the changes over the Indian and East Indian areas.

The conclusion to be drawn from all the curves above referred to is that while they all indicate somewhat similar variations of long duration, yet there seems, on the whole, to be a difference between the variations over the Indian and Australian areas.

* Roy. Soc. Proc., A., Vol. 78, 1906, page 43.

† Roy. Soc. Proc., A., Vol. 78, 1906, page 48.

It has been previously stated (page 72) that in discussing the pressure variation of about four years duration, the changes indicated by the Cape Town barometer seemed to be intermediate between those shown by the South American and Australian barometers.

An attempt was therefore made to see whether any variation of long duration was exhibited in the Cape barometric observations, and to compare it with those previously found for South America, Australia, and India. As a good series of barometric observations of Durban was at the same time available, this station was discussed as well.

For both stations four-year mean values were determined, and curves drawn in the usual manner. Both of these are reproduced in Plate 10, from data given in the Appendix (Table 10).

In examining the curves the first point that strikes one's attention is that the curves differ from one another in many respects. Thus the minimum about the year 1880 at Durban is not repeated at Cape Town. The high values for the years 1881 to 1883, which make the curve indicate a maximum at this epoch, do not correspond to the maximum in the Durban curve, which occurs about the year 1888.

When one comes to compare these curves with those of India, East Indies, and Australia, one is very inclined to throw doubt on the Cape observations about the year 1880, because the Cape curve *about that epoch alone* differs not only from that of Durban but from those of India and Australia, with which Durban agrees. If, therefore, the Cape curve for the interval 1879 to 1884 be omitted from the discussion, then it will be seen that the two South African curves bear a close resemblance to the Indian, East Indies, and Australian curves, but approximate more to the Adelaide variation than to that exhibited by Sydney.

If the South African curves be compared with that of Cordoba, which represents the South American type of variation, their dissimilarity will be at once observed (Plate 10).

One is thus led to the conclusion that, so far as the variation of long duration is concerned, South Africa must be associated directly with the Australian and Indian regions, and more especially with the latter, and not with South America.

A study of Plate 10 will show the inter-relationship between all the barometric curves to which reference above has been made.

Possible Origin of Variations of Long Duration.

In looking for the cause of these barometric changes which extend over several years, I have suggested* that possibly solar changes, as exhibited by the

* Proc. Roy. Soc., A., Vol. 78, 1906, page 55.

frequency or areas of sun-spots (the only indication of solar activity extending over a long period of time that exists) may be responsible for the Indian fluctuations. To indicate this relationship the sun-spot curve (inverted) is placed at the top of Plate 10.

This curve represents the variation from year to year of the mean daily areas of sun-spots deduced from both hemispheres of the sun. Perhaps different solar data handled in another manner may indicate at some future date a closer relationship than is at present suggested.

Although this existing relationship may be considered of too approximate a character to indicate clearly a cause and effect, there is undoubtedly a general similarity between the sun-spot variation curve and that representing barometric changes in India from 1844 to 1903, a period of 59 years. Years of average high pressure are years of few sun-spots, and *vice versâ*, but there is a marked exception to this about the epoch of sun-spot maximum in 1883, which maximum was much smaller in intensity than those of 1870 and 1860. If India be thus dominated by the solar changes, then the curves for Australia and South America become of secondary importance from the solar point of view, and may be considered as a modification of the Indian variation, due possibly to some terrestrial cause. How this modification is brought about I am not yet prepared to say, but I do not think we need be driven to explain the Australian or the South American barometric changes as depending either on lunar influence or a solar variation of about 19 years.

The similarity of the curves representing the pressure changes in India and the sun-spot curve is not pointed out here for the first time. In fact, so striking was the resemblance between curves representing these changes in years previous to 1880 that the attention of several meteorologists was drawn to the close association of these two phenomena.

Thus F. Chambers, writing in 1878,* concluded that the curves "support "each other in showing a low pressure about the time of sun-spot maximum and "a high pressure at the time of sun-spot minimum." He further stated:—

"The range of the variation of the year by mean pressure from the minimum of 1862 to the maximum of 1868 is 0·042 inch, and the mean range of the barometer from January to July is 0·291 inch, from which it appears that the variation of pressure produced by the absolute variations of the sun's heat are, in comparison with the usual seasonal changes, by no means insignificant."

J. A. Brown,† S. A. Hill,‡ Sir John Eliot,§ H. F. Blanford,‖ E. Douglas Archibald,¶ and others, have all corroborated in a general manner this relationship

* "Nature," Vol. 18, page 568.

† "Nature," Vol. 19, page 7. 1878.

‡ "Nature," Vol. 19, page 432. 1878.

§ "Indian Meteorological Reports," page 170. 1877.

‖ "Nature," Vol. 21, page 479. 1880.

¶ "Indian Meteorological Memoirs," Vol. 9, page 543. 1897.

between pressure change and sun-spot variation; Douglas Archibald used data which extended up to the year 1893, and his deductions, which I think are the most recent, were:—

"The mean anomalies present all the characteristics of a true period, rising to a maximum of 0·0132 inch about the epoch of minimum sun-spot, and, with an exception in the sixth year, falling to a minimum of 0·0100 inch coincidently with that of maximum sun-spot, the former barometric epoch slightly preceding, and the latter slightly following, the corresponding solar epoch as is usual in all other sun-spot comparisons. . . ."

"Still the figures from the other years, and the repetition in each cycle, show that there is a cyclical tendency to high pressure at the time of few spots and low pressure at the time of many spots . . . . the amplitude of the variation amounts to 0·02 inch . . . ."

By utilising in this inquiry observations made up to the most recent date possible, 1905, it will be seen (Plate 10) that the sun-spot maximum of 1893 corresponded with an epoch of mean low pressure about that epoch; while up to 1901, a year of about sun-spot minimum, the pressure had steadily risen. It is thus evident that the same relationship is still in operation, only the amplitude is much smaller than was the case in the earlier years of observation.

Further Discussion on other Views that have been expressed.

Before leaving this subject of the variations of long duration of the barometer in the above regions and their possible origin, reference may be made to some recent work by Colonel A. E. Rawson, C.B., R.E., in which he has discussed the South African barometric changes.

In a paper entitled "The Anticyclonic Belt of the Southern Hemisphere," * his inquiry leads him to the conclusion that there are changes of long duration indicated by the South African barometers. The changes, according to him, display a nineteen-year period, or, as he states, the anticyclonic belt has a movement in latitude and "performs its double oscillation in a period of 19 years."

A certain ambiguity arises with the use of the term "double oscillation," for it is uncertain whether one or two *complete* oscillations are meant.

Since, however, he stated that the period in question was of 19 years duration, and accompanied his remarks with only the values of the Cape pressures for the years 1845, 1865, and 1884, pointing out that these years (about 19 years apart) exhibited exceptionally high pressures (and therefore, presumably, the intervening years were not so high), one is led to infer that his "double oscillation" means a "*complete* oscillation" and that the Cape yearly values exhibit maxima about every 19 years.

* Quart. Jour. Roy. Met. Soc., Vol. XXXIV., No. 147, July 1908, page 165.

This deduction as to a "*complete* oscillation" seems further corroborated by another table which he gives showing the cyclical changes of the belt's latitude and years of reaching its extreme and mean positions.

This table is as follows:—

Anticyclonic Belt.	Lat.	Years.	Interval.
			Years.
Extreme northerly position - -	$24\frac{1}{2}°$ S.	1855, 1874, 1893 - - -	19
Mean position - - - -	$29\frac{1}{4}°$ S.	1850, 1859, 1869, 1878, 1888, 1898	9·5
Extreme southerly position - -	34° S.	1845, 1865, 1884, 1903 - -	19

According to the above table the pressures at the Cape should have exceptionally high values about the years 1845, 1865, 1884, and 1903, and very low values about 1855, 1874, and 1893, because the Cape would be more under the influence of the anticyclonic belt in the former series of years than in the latter.

During the intervening years, as given in the tables, the Cape pressure should have a mean value.

In a preceding part of this memoir I have already (page 76) referred to the variation of long duration of the pressures in South Africa, using the observations made at Cape Town and Durban, and I pointed out that the changes found indicated a closer resemblance to those occurring in the Indian area than to those taking place in Australia as represented by the Sydney, Melbourne, and Perth curves. The Indian curves, it will be remembered, resembled closely the inverted sun-spot curve (Plate 10), or had a variation of about 11 years, while the three Australian curves above mentioned suggested a 19-years variation. This result as regards the Cape pressures is not, therefore, in accordance with that found by Colonel Rawson, who suggested a 19-years variation for South Africa.

In dealing with a variation of long duration extending over many years it is important to eliminate as far as possible, in the first instance, changes the duration of which complete a cycle in three or four years. To this end, therefore, four-year mean values are preferable to the annual mean values. A curve representing the variation of the mean annual values of Cape Town from 1860 to 1904 is given in Plate 8,* and it will be seen how difficult it is to differentiate between the various peaks of the curves.

If, however, one restricts oneself for a moment to mean annual values, it is found that between the years 1845 and 1865, for which years the pressures were 30·057 and 30·035 inches respectively, and which Colonel Rawson considers as years of exceptionally high pressures, the pressures for the years 1853, 1854,

* In this plate the Cape curve was not plotted for years previous to 1860, as it was unnecessary for the object of which the plate was made.

1855, and 1856 were 30·047, 30·049, 30·052, and 30·043 inches, all higher values than that recorded for 1865. Again, he looks upon the pressures for the years 1865 and 1884 as abnormally high, values 30·035 and 30·049 inches respectively, but disregards such intervening years of high pressure as 1874 with 30·044 inches and 1876 with 30·052 inches.

If, however, we consider the four-year mean values and examine the curves made up from them, the sequence of changes can be clearly discerned. Such curves for Cape Town and Durban are reproduced in Plate 10. I have previously referred to the disagreement between these curves (page 76) for the years 1880 to 1884.

The most prominent maxima and minima of these two four-year mean curves can now be easily picked out, and leaving out of account the Cape curve after the year 1879, the epochs and values thus derived are shown in the following table:—

TABLE SHOWING YEARS AND VALUES OF THE MOST PROMINENT MAXIMA AND MINIMA IN THE FOUR-YEAR MEAN CURVES.

Years of Maxima.	Cape Town.	Durban.	Interval in Years.
1842–1845 - - - -	30·043	—	
			11
1853–1856 - - - -	30·048	—	
			12
1866–1869 - - - -	30·038	—	
			8
1874–1877 - - -	30·040	30·108	
			13
1887–1890 - - - -	—	30·113	
			11
1898–1901 - - - -	—	30·107	
		Mean -	11
Years of Minima.			
1849–1852 - - - -	30·016	—	
			10
1859–1862 - - - -	30·014	—	
			11
1870–1873 - - - -	30·016	—	
			8
1878–1881 - - -	—	30·084	
			14
1892–1895 - - - -	—	30·088	
		Mean -	10·7

The two chief facts to be derived from this table are as follows:—First, whether the intervals between the consecutive maxima or minima of the curves be considered, the mean interval between their occurrence is about 11 years.

Second, the years of maximum pressure congregate about the years of sun-spot minima epochs, while the years of minima pressure occur about the times of the epochs of sun-spot maxima.

These results clearly show that, so far as the data that have here been employed are concerned, the variation of pressure in South Africa has not such a very definite 19-year variation, but one covering a little more than half this period.

Whatever may be the length of the variation that is really in existence, Colonel Rawson suggests that the origin of the barometric changes is the movement in latitude of the anticyclonic belt.

Towards the latter portion of his paper (page 182) he refers to the work of Mr. Russell regarding Australia. He says: "On turning to Mr. Russell's con-" clusions regarding that of Australia there seems to be a cyclical variation of " the belt there also, which corresponds very closely with that which is given " in Table XIV. He was led to advance the theory that there is a general " periodic occurrence of seasons every 19 years, and that during every cycle of " 19 years there are two periods of good seasons and two periods of bad seasons, " due to droughts, besides minor fluctuations."

The Table XIV. referred to in the above quotation is that given here on page 79.

From the above quotation Colonel Rawson suggests that the barometric change from year to year in Australia is also due to the variation in the position of the anticyclonic belt, but, so far as I am aware, Russell himself did not definitely state this as a cause.

Colonel Rawson puts forward the idea, however, that "Mr. Russell's theory " probably rose out of the existence of the belt's double oscillation over Australia."

Leaving Australia for a moment, and dealing with Natal, Colonel Rawson refers to the important statement made by Mr. E. Nevill, the Government Astronomer of Natal, which appears in his annual report for the year 1893–1894 :—

"Natal is on the border of a great southern anticyclonic belt, and it would appear that it is the position and condition of this belt which mainly regulates the climate of Natal. As the position of this belt probably is cyclic in character, with a period approaching nine years or a multiple thereof, a knowledge of its position and condition for the preceding years will afford the means of judging of its probable character for the coming year, and thus for predicting the nature " of the coming season."

Mr. Nevill, it will be seen, throws out the view that the position of the anticyclonic belt about Natal is only probably cyclic in character, but he does not state that the variation has a 19-year period, but a period "approaching nine " years or a multiple thereof."

If the reader will glance at Plate 10 in this memoir he will see that the curve there shown, indicating the variation from year to year of the four-year mean pressure values at Durban, render three maxima prominent, namely, at the epochs 1876, 1889, and 1900. The intervals between these maxima are 13 and 11 years respectively, or 12 years in the mean. The shorter period given by Mr. Nevill seems therefore to come closer to the interval here found than the multiple of nine years of which he speaks.

Mr. Nevill not only speaks about the position of the anticyclonic belt, but also of the *condition* of it. It is this latter factor which may prove to have a more important bearing on these pressure variations of long duration, than their position in latitude.

With the object of attempting to throw some light on this question the data for Adelaide have been examined.

Reference may first be made to the tables on page 29, in which the numbers of anticyclones and low-pressure areas were given for the three years 1891, 1892, and 1893, years of high, average, and low pressures respectively.

Although only three years were examined, their mean annual pressure values were so different that they represented good epochs for showing any great changes, if such occurred.

The figures there suggest that the year which has the lowest mean pressure, namely, 1893, is also the year in which the greatest number of low-pressure areas is recorded. Thus for the six months (April to September) the numbers for the years are 5 for 1891, 15 for 1892, and 23 for 1893.

In the case of the high-pressure year 1891 there does not seem to be a greater number of anticyclones recorded, the number for the six months (October to March) being 36, 41, and 35 for 1891–1892, 1892–1893, and 1893–1894 respectively.

Russell also found* that the average number of anticyclones passing over Australia, so far as the observations he discussed went, varied but little.

It seemed at first quite possible, however, that the number of low-pressure areas may, in low-pressure years, be increased by assuming that the mean track of the anticyclones is a little nearer the equator at those epochs. The low-pressure areas would thus have a slightly more northerly course, and would therefore be more felt and therefore more prominently recorded by the South Australian barometers, which would then not be so much under the influence of the anticyclones.

There does not, however, seem to be sufficient evidence at present to warrant such an assumption, for the data available do not indicate that years of deficient pressure in South Australia correspond to years when the mean track of the anticyclonic belt occupies a more northerly position.

Russell some years ago determined the mean monthly and annual latitudes of the anticyclones, so it is possible to compare these values directly with the pressure values for Adelaide.

* Quart. Jour. Roy. Met. Soc., Vol. XIX., No. 85, January 1893, page 24.

In the accompanying table these data are placed in vertical columns :—

Year.	Latitudes of Anticyclones.	Barometric Pressure. Adelaide.
	°	Inches.
1889 - - - - -	33·6 S.	1·058
1890 - - - - - -	33·1	1·036*
1891 - - - - -	34·1	1·111
1892 - - - - - -	34·4	1·054
1893 - - - - -	35·9	1·022*
1894 - - - - - -	34·3	1·067
1895 - - - - -	34·4	1·070
1896 - - - - - -	34·5	1·079
1897 - - - - -	33·7	1·076
1898 - - - - - -	34·9	1·038*
1899 - - - - -	35·8	1·084
1900 - - - - - -	34·7	1·055

It will be noticed in the first instance that the changes in latitude of the anticyclonic track from year to year are really very small, and it may be questioned whether such a small difference between the greatest and least values, namely, 2°·8, is either large enough to explain the changes in question or is not within the error of their determination.

If the three smallest pressure values be picked—these have been marked with an asterisk—only one out of the three indicates a low latitude with a low value of pressure. The low pressures of the years 1893 and 1898 correspond to comparatively high latitudes, that for 1893 being the highest latitude of the whole series of years analysed.

These figures, therefore, do not corroborate the above-suggested movement of the anticyclonic track to account for the increase in the recorded number of low-pressure areas.

Another cause that may be suggested is that, instead of the anticyclonic track moving in latitude, the individual anticyclones may be altered in character, as Mr. Nevill suggested. If this be so, they may be of smaller intensity in some years, and so do not possess the barring influence to resist the inroads of the depressions. This explanation not only may account for the low pressures of some years, but helps to explain the result mentioned above, namely, that the number of anticyclones does not alter very much, whether the pressure is high or low, during any year.

This cyclic diminution or increase in the intensity of the anticyclones would account for the movements of the north and south fringes of the so-called anti-cyclonic belt, and would thus explain the other meteorological changes which have been associated with the suggested latitude movement of the belt.

L 2

The fact that there is much evidence to show that the anticyclones are individually of much greater intensity in high than in low-pressure years has already been pointed out on page 19.

One is inclined, therefore, to explain the barometric changes above discussed as due to change of *condition*, and not to change of *path*, the former being caused by either direct or indirect solar action.*

* *See* Addendum, following the Appendix, for a further discussion on the latitudes of the anticyclones.

Chapter X.

THE SIMILARITY OF AIR MOVEMENTS OVER AUSTRALIA, SOUTH AFRICA, AND SOUTH AMERICA.

THE SIMILARITY OF AIR MOVEMENTS OVER AUSTRALIA, SOUTH AFRICA, AND SOUTH AMERICA.

It has been stated in a previous chapter (page 13) that Australian weather is the product of a series of rapidly moving anticyclones, which follow one another with great regularity, and which move at the rate of about 400 miles a day.

A study of the isobars from day to day on the daily weather charts shows clearly that these *anticyclones arrive on the west coast as complete systems,* and are not formed as Australia is reached, although they may suffer some modification in intensity and form when they reach the land, according to the season of the year.

So convinced was Mr. H. C. Russell of the long life of these travelling anticyclones, that he was led to determine whether they had previously passed over South America and South Africa before they reached Australia.* This investigation is of such importance that one may sum up here the results he obtained in his own words, published in the volume to which reference has just been made :—

"The two methods of determining the velocity of anticyclones, that is, over Australia alone, where it is 400 miles per day, and over the space from Natal to Sydney, where it is 458 miles per day, seem to leave no doubt as to their persistence. For if they can thus be followed one-third of the circumference of the earth, *i.e.*, from Natal to Sydney, it may safely be assumed that they travel the other two-thirds of the way, and that they keep up their general characteristics. What influence that great obstacle in their path, the Andes of South America, may have on them I am not at present in a position to say, but I have no doubt, from what we see so clearly in the influence of our own comparatively small range of mountains along the east coast of New South Wales, that it is a very material one.

"If from Buenos Ayres we could get by cablegram the state of the weather from day to day, we should be in a position to forecast the coming weather for about a month in advance; and it may yet be that when our investigations, which are now in progress, are completed we shall be able to forecast far longer periods. If, for instance, we could ascertain the velocity of the translation of the anticyclone round the other two-thirds of the globe, as we have done for the one-third from Natal to Sydney, or rather more than one-third because it extends to New Zealand, then we could ultimately forecast the return, in say seven weeks, of weather passing over Sydney. Certainly the discovery of the daily translation of anticyclones in our latitude, over such a large section of the circumference of the globe, holds out a reasonable hope that they may be traced all round, and the proportion of water surface points clearly to the fact that the conditions are more favourable here than

* Three Essays on Australian Weather. "Moving Anticyclones in the Southern Hemisphere," by H. C. Russell. 1893, page 9.

in any other part of the earth for normal atmospheric circulation. I do not by this intend to convey the idea that I think an anticyclone keeps its shape, size, form, and peculiarities for weeks together, because I see them changing every day. But nevertheless there are obvious peculiarities which affect some anticyclones—general characteristics I mean, such as dryness or moisture—which, it may be, are attached to them more persistently than the mere form of the isobars. And if so, it will afford good data for long-period forecasting."

In order, if possible, to throw further light on this question by employing more recent data, the barometric conditions which prevail during a year in South Africa and South America have been examined.

Dealing with South Africa in the first instance, the inquiry is facilitated by the recent publication of an important paper on "The Barometer in South Africa," by R. T. A. Innes.*

Reading this paper with the knowledge of Australian barometric changes, it is found that practically the same kind of conditions prevail, remembering at the same time that the most extreme southern portion of South Africa is in latitude 34° 50′ S., while that of Australia is about 39° S.

Just as Australian weather is controlled by a sequence of anticyclones passing from west to east, and that of its southern portion by inverted V-shaped depressions carried along between them, so that of South Africa is dominated by similar conditions. A comparison made between the seasons at each of these countries brings out their similarity very closely.

Taking the winter conditions (April to September) first, the anticyclones take a course nearer the equator in both these regions. In both countries high pressure prevails, while the southern "lows" in both cases skirt the southern coasts.

The effect of these lows is felt more in Australia than in South Africa, because the former country extends further to the south and becomes more enveloped in them.

During this season both countries receive their rainfall on the west, south-west, and southern districts, brought by these southern lows.

During the summer months (October to March) the anticyclonic track in both countries occupies higher latitudes, and the pressure is reduced in each case. The southern lows are now kept well south, and in neither country can they affect the land areas. This southern position of the anticyclonic track is favourable in Australia for the monsoonal "lows" to recurve from their south-east course and striking the country as if they came from the north-east, to pursue afterwards a path lying in a south-easterly direction. These monsoonal "lows"

* Report of the South African Association for the Advancement of Science. 1906.

are responsible for the rainfall on the northern, north-eastern, eastern, and south-eastern areas of Australia.

In South Africa precisely similar conditions seem to prevail, for the summer cyclones come from the north-east and recurve to the south-east, skirting the east coast in their passage. Whether these are monsoonal "lows" from the South Indian Ocean which recurve from a south-easterly path to one north-easterly is not yet known for certain. If they are, then they should reach the east coast of Africa from the north-east and recurve again towards the south-east. These summer "lows" bring the rainfall to the east and south-east coast, just as they do in the case of Australia.

In the same way as the south-east region of Australia, New South Wales, is so situated that, during a year, it is affected by both the monsoonal and southern "lows," so the extreme south coast of Africa comes under the influence of the two seasonal sets of depressions. Both these regions are in about the same latitude, namely, 32° S. The distribution of the seasonal rainfall of South Africa is well stated by Mr. C. M. Stewart,* who says that :—

"Mr. A. Struben found† that South Africa could be conveniently divided into three distinct areas, according to the percentage distribution of the rainfall falling during the two above-mentioned periods. He accordingly sub-divided the country into the following three regions‡ :—

"(1) *Summer rainfall area*, having over 50 per cent. of the total rainfall from October to March.

"(2) *Winter rainfall area*, having over 50 per cent. of the total rainfall from April to September.

"(3) *Constant rainfall area*, having the rainfall equally divided between these two periods."

"The region of constant rainfall is confined to a comparatively small area on the south coast, extending from a point some distance east of Mossel Bay to Humansdorp, and stretching inland to the neighbourhood of Uniondale."

"It will be seen from the 'Seasonal Rainfall' map that the dividing line of 50 per cent. separating the summer and winter rainfall areas starts on the 28th parallel about 17° 40′ E. longitude,§ passes in a sweeping curve (at first convex, then concave, to the west coast) in a general S.S.E. direction to the neighbourhood of Ladismith (lat. 33° 29′ S., long. 21° 17′ E.), whence it turns in a direction a little south of east to reach the coast about Port Alfred

* "Science in South Africa," 1905, page 27.

† Report of the Meteorological Commission for the Year 1897.

‡ *See*, however, "An Introduction to the Study of South African Rainfall," by J. R. Sutton, B.A. Trans. S.A. Phil. Soc., Vol. XV., Part 1, pages 1–28.

§ If the map were made to include the coast line of German South-West Africa, and the lines extended accordingly, it would be probably found that the 50 per cent. line would emerge on the West Coast about the 25th parallel 2° S. of Walfish Bay.

(lat. 33° 34′ S., long. 26° 54′ E.). All the land to the north and east of this line belongs to the summer rainfall area, and all to the south and west to the winter rainfall area, with the exception of the area of constant rains already noted."

"It must not be forgotten that the above sub-division of the country into three rainfall areas is based upon the relative quantity of precipitation, and has no reference to the absolute quantity, which varies considerably over South Africa."

Another point of similarity between the anticyclones over Australia and South Africa is their rate of movement. Russell, as mentioned previously, gave the mean daily rate of translation derived from all available records over Australia as 400 miles, and over the sea and land, from Natal to Sydney, as 458.

Innes, from observations made in South Africa, finds that barometric changes at the Cape are practically repeated at Johannesburg 36 hours later: this means that the anticyclones move there at the rate of about 380 miles per day. The speed over South Africa is therefore quite in accordance with that over Australia.

Although no mention is made of anticyclonic systems travelling over the South Indian Ocean, Commander Campbell Hepworth gives an interesting account of the movements of the southern depressions over the ocean from the Cape to Australia in his "Notes on Maritime Meteorology" (1907, page 54). The paper in question is entitled "Wind Systems and Trade Routes between the Cape of Good Hope and Australia," and is the result of the examination of a large number of ship's logs.

He found that the cyclonic disturbances followed paths which are south of the 43rd parallel during the winter months, and south of the 46th parallel during the summer months.

This change of latitude of the cyclonic track thus harmonises with the movements already referred to, when they pass near the continent of Australia.

To make the most favourable passages from the Cape to Australia it is necessary to take a course on which the greatest amount of westerly wind can be experienced. Such a course will be that which skirts the northern portion of the cyclones. This, according to Commander Hepworth, is to the northward of the 42nd parallel in the winter months, and somewhat to the northward of the 46th parallel in the summer months.

This change in the seasonal position of the tracks of these southern depressions is, with little doubt, regulated by the sequence of anticyclonic areas which lie adjacent to the northern parts of the depressions. Westerly winds will therefore be found just as much on the southern borders of the anticyclones as on the northern portion of the cyclones, although, perhaps, they may be stronger in the latter case than in the former.

Commander Hepworth gives many instances of the easterly progress of these southerly depressions, which seem to clearly show that in this southern part of the ocean we have to deal with a series of *separately moving cyclonic whirls*, as is experienced on land, and not a simple extensive air movement from west to east. One example will illustrate the nature and movement of such depressions:—

"These systems of low atmospheric pressure frequently travel to the eastward, for days, at so slow a rate of speed that a steamer running on the left-hand side of their centres will often keep up with them for hundreds of miles, sometimes overtake them, and not unfrequently leave them astern. In July 1887, the S.S. *Port Pirie* ran on the left front of such a system for upwards of 1,200 nautical miles, or nearly 1,400 statute miles, and would in all probability have remained under its influence for hundreds of miles more had she continued her onward progress; but having been stopped and hove-to under canvas in order to effect some repair to machinery, the trough of the depression within three hours passed the ship. . . . The *Port Pirie* had been making about 300 miles per day while in company with this system."

In this case the velocity of the depression is quite in accordance with the experience of South Australia.

Coming now to the South American region, it is found that practically the same sequence of changes occurs during a year as has been shown to be the case in South Africa and Australia. As the extreme southern portion of South America is in about latitude 56° S., the belt lying between latitudes 20° S. to 40° S. need only be considered here for comparison with the other two countries.

The data which have been employed have, in the case of the Argentine Republic, been taken from the valuable memoir on "Climate of the Argentine Republic," by Mr. Walter G. Davis, director of the Argentine Meteorological Office, and, in the case of Chili, from various numbers of the "Meteorologische Zeitschrift."

Dealing with the pressure conditions first, it is very clearly shown that the country lying between latitudes 25° S. and 35° S. is continually being swept by a succession of anticyclones, while to the south, about latitudes 40° to 50° S., a series of cyclones transit the country.

Although it is difficult to determine the mean latitudes of the summer and winter anticyclones without analysing a great number of daily weather charts one is able to see that the tracks of the anticyclones and their attendant cyclones exhibit a march in latitude according to the season of the year. In the winter months they travel nearer to the equator than they do during the summer months, as was seen to be the case with those in South Africa and Australia.

Most interesting is a study of the mean annual pressure variation-curves of several stations in the Argentine Republic arranged in order of latitude. Here

is found, just as was experienced in Australia, that the curves have single maxima in the year at stations in low latitudes, while in higher latitudes the single maximum is converted into a double one. For Australia the latitude where this change appeared to commence was about 24°; in the case of South America the latitude is about 32°. (*See* page 26.)

Turning our attention now to the rainfall of the two regions, the Argentine Republic and Chili, we here find two quite distinct seasonal rainfalls. In the Argentine Republic north of latitude 38° S. the rainy season comprises the summer months, October to March, the maximum fall occurring in January. In Chili, in the same latitudes, the rainy season is confined to the winter months, the maximum fall taking place in June.

Further south, about latitude 40° S., regions are met with which receive rain at both seasons of the year.

It is important to note that when the rainfall occurs on the west coast the path of the anticyclones is nearer the equator and affords the southern cyclones an opportunity of reaching lower latitudes and watering the country. In the other season of the year, when the east coast receives its annual rainfall, the anticyclones are in higher latitudes, and thus allow the monsoonal lows from the South Atlantic ocean to reach higher latitudes. Whether these lows originate in the south-east trades, recurve and reach the Argentine Republic from a north-easterly direction, and eventually pass away in a south-easterly direction, is a matter for investigation, but it seems very probable that such may be the case.

The comparison of the general weather conditions prevailing in these different countries, lying on about the same parallel of latitude, indicates that great similarity exists between them. If, therefore, each of these countries has series of anticyclones passing across them in about the same latitudes, and from west to east, it seems quite reasonable to suppose that valuable meteorological information for any one of these countries could be secured by inquiring about the conditions which prevailed in the country lying more towards the west.

It has been previously indicated that when the pressure over Australia in any one year is in excess, that over South America is deficient, and *vice versâ*. If, therefore, the anticyclones do encircle the earth in the parallel of latitude just referred to, they must suffer some modification as they travel alternately through these regions of relatively high and low pressure.

The following summary brings together the main feature regarding the similarity of the conditions prevailing in the three regions, namely, Australia, South Africa, and South America:—

1. A successive series of anticyclones travelling from west to east cross the countries between latitudes 20° and 35° S.
2. A series of successive "lows," bordering on the south side of the anticyclones, pass also eastward.

3. The monsoonal "lows" recurve from the south-east trades and enter the countries from the north-east or north directions.
4. A seasonal movement in latitude of the anticyclonic tracks takes place, and this controls the positions of the cyclonic tracks.
5. The rainfall on all the east coasts occurs in the same season of the year, namely, October to March.
6. The rainfall on all the west coasts takes place during the winter months, April to September.
7. Each country has a region which receives rainfall during both of these seasons during a year.

In the accompanying figure (Fig. 10) an attempt has been made to illustrate at a glance in diagram form the positions of the anticyclonic tracks and the

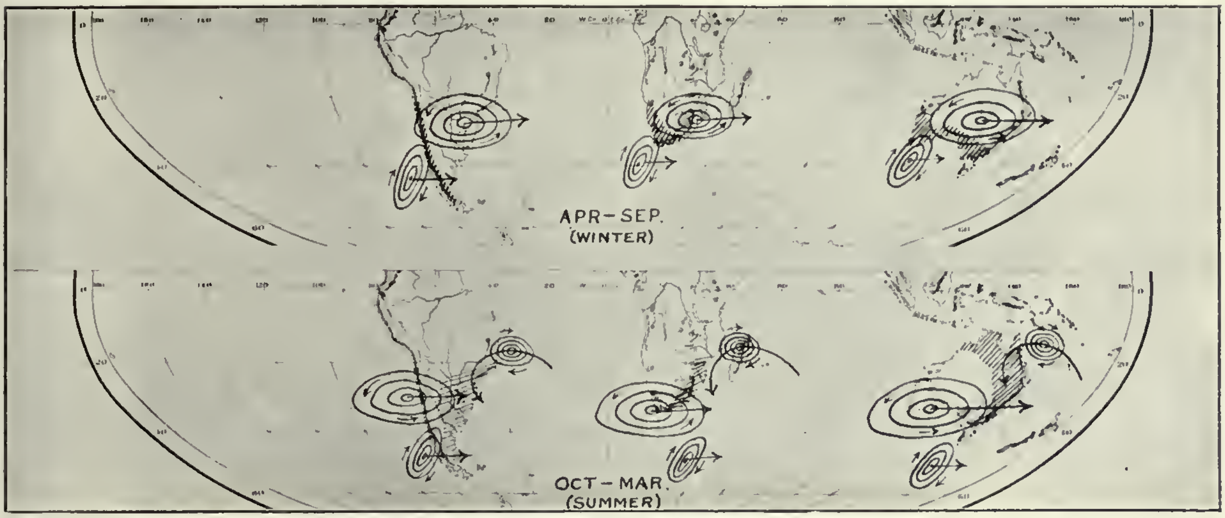


Fig. 10.

regions of the southern and monsoonal low-pressure disturbances, with the accompanying regional rainfall for the two seasons, winter and summer. The small arrows in the isobars indicate the general movement of the air in the systems, while the large arrows show the direction in which they travel. The tendency of the low-pressure systems is to travel with the anticyclones from west to east, but, at the same time, they are trying to wedge themselves in between them and pass through to the opposite side. Both the southern and monsoonal "lows" endeavour to do this, and often succeed.

A glance at Fig. 10 will show the relation between the two wind systems, indicating the advisability of the shipping routes being restricted to the north of the cyclones or to the south of the anticyclones, thus experiencing in both cases westerly winds. It will be seen, further, that if a more southerly route were chosen, ships would either have to pass through the centres of these depressions and experience heavy weather or traverse their southerly portions and meet easterly or opposing winds.

The conclusion that all the three countries, namely, South America, South Africa, and Australia, between about latitudes 20° S. to 35° S., experience series of anticyclones travelling from west to east, renders it very difficult to believe that these systems do not circulate round the earth in those latitudes.

During the winter months, that is, when the anticyclones are nearer the equator, these systems are also distinctly felt at Mauritius (latitude 20° 5′ S.). So clearly are they pronounced in the barometric records there that one can state with certainty that they affect Mauritius about three days after they have been recorded at Durban.

This additional evidence, and more is being collected, still further endorses the view that they cross the southern oceans as individual systems, as Russell suggested.

APPENDIX.

Table I.

PRESSURE.—YEARLY. (January to December.)

Year.	Port Darwin.	Daly Waters.	York.	Carnarvon.	Albany.	Eucla.	Deniliquin.	Goulburn.	Port Augusta.
	29 ins. +	29 ins. +	30 ins. +	29 ins. +	30 ins. +	30 ins. +	30 ins. +	30 ins. +	30 ins. +
1867	–	–	–	–	–	–	·112	–	–
1868	–	–	–	–	–	–	·125	–	–
1869	–	–	–	–	–	–	·176	–	–
1870	–	–	–	–	–	–	·118	29·937	–
1871	–	–	–	–	–	–	·127	30·069	–
1872	–	–	–	–	–	–	·133	·069	–
1873	–	–	–	–	–	–	·132	·075	–
1874	–	–	–	–	–	–	·085	·072	–
1875	–	–	–	–	–	–	·030	·044	–
1876	–	–	–	–	–	–	·064	·077	–
1877	–	–	–	–	–	–	·163	·017	–
1878	·827	–	–	–	–	–	·047	·013	–
1879	·810	–	–	–	–	·028	·034	·039	–
1880	·838	–	–	–	·046	·050	·070	·026	·061
1881	–	·905	–	–	·088	·090	·126	·086	·096
1882	·822	·914	·016	–	·031	·034	·085	·040	·031
1883	·819	·933	·042	–	·041	·050	·094	·053	·054
1884	·844	·952	–	–	·044	·056	·124	·065	·067
1885	·862	·980	·065	·980	·093	·090	·146	·106	·115
1886	·813	·890	–	·940	·071	·061	·119	·064	·064
1887	·829	·897	·049	·962	·073	·056	·100	·052	·066
1888	·856	·931	·065	·987	·096	·089	·141	·093	·104
1889	·831	·891	·010	·964	·026	·027	·107	·062	·045
1890	·813	·873	·001	·951	·034	·018	·084	·039	·008
1891	·862	·905	·068	·998	·108	–	·153	·064	·079
1892	·826	·866	·036	·960	·056	·045	·108	·035	·029
1893	·826	·861	·001	·922	·010	·010	·071	·024	·004
1894	·831	·880	·054	·940	·076	·065	·152	·069	·043
1895	·861	·893	·057	–	·058	·061	·144	·072	·051
1896	·894	·914	·049	·973	·058	·066	·138	·070	·062
1897	·878	·901	·056	·962	·056	·065	·126	·066	·070
1898	·847	·863	·016	–	·021	·017	·094	·060	·026
1899	·899	·908	·048	·984	·056	·051	·106	·092	·070
1900	·903	·915	·056	1·002	·062	·036	·066	·074	·052
1901	·898	·899	·054	1·004	·078	·058	·107	·102	·074
1902	·922	·919	·071	1·019	·077	·060	·109	·109	·085
1903	·883	·878	·026	·966	·038	·017	–	–	·040
1904	·887	·896	·042	·997	·039	·011	–	–	·063
1905	·920	·910	·070	1·024	·077	·067	–	–	·072

Table 2.

PRESSURE.—PERTH.

Lat. S. 31° 57′, Long. E. 115° 45′. Elevation of Cistern 197 ft. Noon Readings. After 1884, Mean of 9 a.m. and 3 p.m.

Year.	29 inches +												Mean for	
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	Four Years.
1876 -	·818	·931	·971	1·135	1·138	1·151	1·229	1·150	1·099	1·029	·928	·996	1·048	
1877 -	·931	·931	1·103	1·159	1·073	1·327	1·140	1·191	1·232	1·103	1·072	1·005	1·106	
1878 -	·939	·960	·995	1·056	1·133	1·071	·972	1·090	1·006	·997	1·005	·907	1·011	1·050
1879 -	·904	·924	1·052	1·276	·969	1·022	1·141	1·135	1·091	1·137	·984	·897	1·044	1·044
1880 -	·814	·877	·934	1·028	1·047	1·067	1·179	1·069	1·194	1·075	·990	·972	1·013	1·030
1881 -	·913	·971	1·019	1·098	1·087	1·136	1·176	1·210	1·140	1·053	·915	·897	1·051	1·032
1882 -	·956	·936	·964	·930	1·109	1·135	1·127	1·014	1·101	1·038	1·010	·903	1·019	1·031
1883 -	·918	·951	1·023	1·050	·995	·971	1·200	1·126	1·207	1·094	·971	·952	1·041	1·038
1884 -	·951	·959	·962	1·054	1·144	1·060	1·211	1·074	1·094	1·077	·958	·953	1·041	1·039
1885 -	·974	·960	1·030	1·110	1·046	1·186	1·090	1·078	1·134	1·110	1·048	·922	1·057	1·056
1886 -	·996	·928	1·061	1·170	1·150	1·252	1·134	1·048	1·044	1·146	1·091	1·012	1·086	1·063
1887 -	·956	·960	1·048	1·129	1·138	1·129	1·127	1·067	1·118	1·118	1·018	1·004	1·068	1·072
1888 -	·908	·994	1·075	1·123	1·111	1·095	1·216	1·176	1·118	1·112	1·012	·993	1·078	1·065
1889 -	1·008	·974	1·084	1·050	1·036	·969	1·173	1·120	1·036	1·044	·937	·912	1·029	1·048
1890 -	·904	·917	1·040	1·084	1·043	1·024	1·162	1·098	1·020	·915	1·065	·941	1·018	1·052
1891 -	·928	·983	1·036	1·132	1·065	1·106	1·258	1·216	1·150	1·074	1·066	·982	1·083	1·044
1892 -	·935	·976	·926	1·162	1·136	1·196	1·094	1·008	1·100	1·084	1·005	·954	1·048	1·040
1893 -	·890	·879	1·045	·976	1·027	1·121	1·038	1·194	1·006	1·010	1·022	·918	1·010	1·051
1894 -	·934	1·017	1·006	1·135	1·160	1·114	1·194	1·096	1·096	1·070	1·006	·924	1·063	1·048
1895 -	·927	·982	1·102	1·157	1·206	1·088	1·138	1·035	1·097	1·080	1·053	·975	1·070	1·050
1896 -	·872	·954	·956	1·138	1·171	1·058	1·102	1·164	1·178	1·100	·984	1·013	1·058	1·063
1897 -	·939	·990	1·029	1·106	1·154	1·028	1·180	1·183	1·087	1·080	1·014	·956	1·062	1·053
1898 -	·910	·860	·964	1·200	1·122	1·076	1·120	1·008	1·085	·966	1·097	·931	1·021	1·047
1899 -	·944	·944	·964	1·041	1·168	1·062	1·130	1·186	1·142	·968	1·042	·982	1·048	1·044
1900 -	·980	·975	1·088	1·054	1·168	·928	1·090	1·046	1·172	1·043	·986	1·007	1·045	1·043
1901 -	·953	·915	1·018	1·071	1·108	1·103	1·204	1·101	1·136	1·102	1·046	·945	1·058	1·058
1902 -	·884	·990	1·040	1·120	1·104	1·186	1·188	1·209	1·088	1·116	1·082	·982	1·082	1·056
1903 -	1·000	1·000	1·035	1·060	1·156	1·111	1·155	1·092	1·009	·966	·970	·909	1·041	1·059
1904 -	·938	·966	·983	1·086	1·169	1·059	1·112	1·156	1·088	1·031	1·093	·966	1·054	1·064
1905 -	·994	1·036	1·100	1·104	·932	1·181	1·157	1·196	1·082	1·118	1·050	·984	1·078	
1906 -	·918	·950	1·024	–	–	–	–	–	–	–	–	–	–	–

Table 2—*continued.*

PRESSURE.—MELBOURNE.

Lat. S. 37° 50′, Long. E. 144° 59′. Elevation of Cistern 91·3 ft. Reduced to 32° F.

Year.	29 inches +												Mean for	
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	Four Years.
1859 -	·838	·833	·943	1·014	·893	1·066	1·143	·934	·969	·860	·953	·847	·941	
1860 -	·739	·933	·915	·952	1·008	·917	1·195	1·168	·929	·958	·835	·844	·952	
1861 -	·833	·793	·956	1·008	·981	·832	·965	1·078	·942	·837	·928	·749	·900	·928
1862 -	·825	·851	·917	·979	·923	1·012	·832	1·060	·825	1·047	·888	·839	·918	·916
1863 -	·816	·849	·921	1·096	·951	1·062	·868	·971	·978	·652	·780	·783	·896	·914
1864 -	·826	·895	1·071	·966	1·129	1·046	·905	·921	·907	·903	·909	·818	·944	·923
1865 -	·889	·863	·924	1·004	·952	1·106	1·006	1·052	·831	·959	·883	·764	·936	·932
1866 -	·855	·896	1·035	1·069	·976	1·123	1·003	1·044	·873	·797	·878	·903	·954	·938
1867 -	·892	·855	1·021	1·012	1·107	1·033	·917	1·099	·743	·672	·910	·752	·918	·946
1868 -	·837	·937	·957	1·096	1·256	·932	1·068	·933	·936	·917	·967	·833	·977	·947
1869 -	·750	·878	·987	1·081	·955	1·081	1·181	1·050	1·076	·806	·779	·737	·938	·911
1870 -	·801	·911	1·050	·967	1·039	·916	1·053	·793	·925	·955	·872	·876	·930	·943
1871 -	·810	:800	·995	1·059	1·005	·960	·886	·930	·958	·968	·854	·842	·925	·929
1872 -	·806	·963	·925	1·021	1·004	·808	·902	1·018	1·064	·919	·867	·784	·923	·931
1873 -	·942	·885	·983	·956	·980	1·015	1·108	·948	·861	·886	·919	·819	·944	·931
1874 -	·884	·910	·965	1·050	·959	·995	1·069	·893	·790	·999	·834	·815	·930	·921
1875 -	·788	·899	·961	·964	·909	·866	1·128	·881	·971	·818	·709	·743	·886	·923
1876 -	·781	·877	·921	·923	1·102	1·051	1·122	1·036	·920	·826	·741	·866	·931	·935
1877 -	·835	·908	1·033	1·070	·844	1·212	1·188	1·075	1·071	1·007	·858	·821	·993	·929
1878 -	·953	·946	·955	·978	1·068	·909	·910	·912	·804	·808	·853	·769	·905	·937
1879 -	·867	·839	·946	1·092	·891	1·051	1·035	1·020	·911	·875	·736	·766	·919	·936
1880 -	·857	·925	·889	1·019	·887	·996	1·069	·879	·941	·849	·952	·871	·928	·930
1881 -	·833	·939	1·003	1·089	1·019	·939	1·180	1·075	·962	·948	·812	·794	·966	·929
1882 -	·777	·959	·881	·908	·934	·968	·942	·960	·857	·865	·987	·787	·902	·929
1883 -	·899	·745	·977	1·041	·932	·991	1·021	·962	·929	·900	·875	·759	·919	·933
1884 -	·783	·899	1·030	1·075	1·066	·971	1·166	·902	·921	·891	·946	·684	·944	·940
1885 -	·888	·841	·925	1·148	1·074	1·018	1·150	·907	·997	1·050	·978	·949	·996	·955
1886 -	·885	·838	1·022	1·007	1·038	1·250	1·136	·783	·961	·777	·919	·889	·959	·961
1887 -	·808	·856	·926	1·125	1·070	·891	·918	1·125	·834	·882	·952	·915	·944	·973
1888 -	·841	·907	·972	1·177	1·099	·999	·942	1·048	1·082	1·046	·911	·884	·992	·959
1889 -	·862	·887	1·015	1·042	1·082	·758	1·158	1·020	·937	·935	·844	·777	·943	·951
1890 -	·910	·870	1·005	1·105	1·112	·899	·993	·919	·882	·663	·861	·868	·924	·961
1891 -	·809	·921	1·025	1·154	1·233	·980	1·027	1·055	1·029	·894	·945	·753	·985	·944
1892 -	·866	·933	·910	1·007	1·036	1·018	1·064	·903	·856	·889	·840	·781	·925	·929
1893 -	·779	·840	1·013	·870	·883	·995	·926	1·039	·794	·810	·833	·805	·882	·929
1894 -	·784	·926	·920	1·023	1·027	·955	·886	·911	·960	·898	·899	·916	·925	·915
1895 -	·866	·882	1·058	1·017	1·103	·999	·905	·865	·824	·915	·984	·722	·928	·921
1896 -	·817	·930	·940	·910	1·053	·976	·881	1·006	1·027	·958	·984	·895	·948	·937
1897 -	·799	·894	·956	·992	1·029	1·149	1·104	·960	·910	·785	·868	·911	·946	·934
1898 -	·841	·806	·940	1·019	1·087	1·033	·940	1·119	·885	·758	·691	·811	·913	·939
1899 -	·706	·918	·900	·981	1·022	·962	1·170	1·111	1·026	·953	·778	·874	·950	·932
1900 -	·852	·929	·928	·969	1·113	·886	·967	·739	1·009	·864	·921	·845	·918	·932
1901 -	·811	·919	·912	·981	1·106	·939	1·105	1·008	·877	·879	·975	·837	·948	
1902 -	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1903 -	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1904 -	—	—	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 2—*continued.*

PRESSURE.—SYDNEY.

LAT. S. 33° 52′, LONG. E. 152° 11′. ELEVATION OF CISTERN 155 FT. REDUCED TO 32° F.

Year	29 inches +												Mean for			
	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.	April–Sept.	Oct.–Mar.	Four Years.
1858	·775	·919	·970	1·014	·829	1·022	·917	·764	·745	·966	·850	·730	·883	·898	·828	
1859	·815	·755	·851	·933	·888	·971	1·015	·971	·875	·829	·831	·803	·878	·942	·802	·877
1860	·682	·830	·839	·875	·944	·823	1·032	1·105	·941	·851	·770	·783	·873	·953	·792	·859
1861	·765	·698	·886	·914	·896	·856	·801	·991	·952	·801	·862	·686	·842	·902	·791	·848
1862	·763	·770	·862	·870	·857	·921	·813	·952	·783	·961	·805	·726	·840	·866	·807	·842
1863	·760	·714	·879	1·009	·930	·971	·898	·865	·968	·613	·678	·728	·837	·940	·759	·845
1864	·737	·801	·967	·896	1·059	·910	·818	·817	·838	·802	·808	·753	·850	·890	·795	·856
1865	·782	·784	·844	·962	·894	1·043	·917	1·001	·780	·857	·802	·623	·857	·933	·815	·865
1866	·773	·834	·998	1·001	·957	1·019	·912	·999	·812	·732	·745	·818	·883	·950	·799	·886
1867	·790	·776	·933	·885	·975	1·008	·928	1·014	·698	·658	·891	·653	·843	·918	·768	·896
1868	·762	·838	·899	1·026	1·175	·900	1·007	·900	·925	·851	·871	·732	·907	·989	·806	·880
1869	·661	·805	·916	·978	·824	1·000	1·088	1·008	1·002	·752	1·017	·690	·895	·983	·794	·875
1870	·597	·820	·890	·873	·941	·865	·973	·928	1·029	·927	·771	·772	·866	·935	·799	·854
1871	·787	·713	·824	·882	·770	·764	·879	·965	·973	·915	·808	·844	·844	·872	·848	·844
1872	·851	·863	·807	·858	·897	·756	·799	·883	1·017	·920	·814	·722	·851	·868	·836	·846
1873	·857	·801	·874	·844	·946	928	·967	·884	·796	·829	·779	·755	·855	·894	·797	·834
1874	·786	·761	·872	·925	·823	·902	941	·801	·694	·941	·752	·720	·827	·848	·795	·829
1875	·706	·794	·857	·861	·812	·825	1·008	·834	·907	·732	·633	·662	·803	·875	·728	·840
1876	·713	·782	·848	·832	·999	·957	·945	·956	·828	·721	·630	·785	·833	·919	·777	·841
1877	·717	·850	·961	·948	·724	1·117	1·075	1·009	·963	·891	·764	·732	·896	·973	·833	·844
1878	·853	·870	·886	·921	·967	·802	·826	·857	·772	·788	·761	·673	·831	·857	·768	·843
1879	·769	·751	·868	1·016	·707	·927	·938	·917	·775	·820	·633	·668	·816	·880	·757	·838
1880	·776	·852	·793	·940	·779	·903	·906	·854	·858	·778	·759	·771	·831	·873	·802	·837
1881	·753	·842	·910	1·010	·975	·839	1·082	·968	·884	·813	·716	·692	·874	·960	·770	·849
1882	·703	·899	·802	·805	·843	·856	·892	·879	·835	·801	·930	·703	·829	·852	·808	·860
1883	·806	·660	·948	·959	·852	·996	·952	·930	·866	·856	·842	·677	·862	·926	·812	·871
1884	·697	·838	·961	·991	·997	·941	1·051	·874	·896	·791	·867	·592	·875	·958	·772	·886
1885	·807	·755	·822	1·052	·999	·938	1·037	·906	·965	·986	·886	·887	·920	·983	·871	·890
1886	·839	·726	·903	·906	·956	1·155	1·062	·769	·941	·707	·862	·831	·888	·965	·804	·902
1887	·746	·795	·883	1·047	·963	·786	·888	1·018	·791	·809	·871	·910	·878	·921	·843	·892
1888	·769	·843	·857	1·116	1·019	·990	·898	·967	1·020	·931	·831	·806	·921	1·002	·854	·881
1889	·802	·803	·953	1·012	·982	·702	1·070	·975	·885	·902	·782	·705	·881	·938	·830	·889
1890	·871	·796	·925	1·003	1·034	·817	·894	·887	·845	·644	·760	·782	·855	·913	·790	·872
1891	·766	·824	·966	1·027	1·148	·805	·924	·968	·949	·841	·867	·680	·897	·970	·806	·859
1892	·786	·856	·810	·897	·995	·961	·995	·827	·784	·839	·793	·702	·854	·910	·796	·866
1893	·690	·786	·967	·760	·886	·904	·880	1·010	·791	·780	·777	·718	·829	·872	·799	·861
1894	·760	·868	·889	·972	·960	·897	·836	·892	·925	·917	·832	·876	·885	·914	·879	·869
1895	·799	·853	·997	·994	1·037	·951	·877	·878	·786	·890	·897	·683	·878	·920	·829	·883
1896	·770	·870	·861	·905	·968	·832	·822	·926	·965	·911	·950	·845	·885	·903	·855	·874
1897	·728	·813	·884	·890	·953	1·143	·977	·905	·859	·754	·823	·873	·883	·955	·818	·877
1898	·794	·776	·886	·960	·961	·991	·912	1·059	·865	·750	·679	·790	·852	·958	·778	·871
1899	·604	·942	·905	·886	·948	·878	1·061	·986	1·002	·891	·732	·814	·888	·960	·840	·875
1900	·836	·874	·887	·903	·985	·835	·871	·746	·918	·818	·857	·796	·860	·876	·831	·888
1901	·730	·919	·866	·908	1·069	·884	1·004	·939	·905	·868	·966	·768	·902	·951	·825	·886
1902	·698	·779	·870	·989	1·058	1·027	1·004	1·065	·846	·862	·873	·727	·900	·998	·825	·894
1903	·835	·788	·862	·870	·998	·941	·894	1·024	·784	·948	·880	·730	·880	·918	·828	·887
1904	·805	·693	·912	1·069	1·017	·897	·999	·978	·880	·854	·806	·788	·892	·973	·835	·884
1905	·793	·838	·921	1·042	·892	·992	·924	·985	·770	·748	·810	·783	·875	·934	·824	
1906	·812	·879	·913	·949	1·033	·965	·843	1·019	·871	·811	·714	·839	·887	·947	·804	
1907	·741	·869	·848	·861	1·083	1·011	–	–	–	–	–	–	–	–	–	–

TABLE 2—*continued.*

PRESSURE.—ADELAIDE.

LAT. S. 34° 56′, LONG. E. 138° 35′. ELEVATION OF CISTERN 140 FT. REDUCED TO 32° F. AND MEAN SEA LEVEL. MEAN OF 9.0 A.M. AND 3.0 P.M. OBSERVATIONS.

Year.	29 inches +												Mean for					
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug	Sept.	Oct.	Nov.	Dec.	Year.	Apr.–Sept.	Oct.–Mar.	Aug.–July.	Nov.–Apr.	Four Years.
1857	·998	·874	·972	1·196	1·345	·966	1·054	1·192	1·118	1·064	1·020	·942	1·062	1·145	·994	1·065	1·014	
1858	·883	1·002	1·050	1·185	·993	1·162	1·175	1·003	1·001	1·122	·963	·906	1·038	1·086	·991	1·055	1·001	
1859	·945	·967	1·044	1·182	1·072	1·191	1·271	1·102	1·095	1·008	1·013	·940	1·072	1·152	·972	1·043	·984	1·055
1860	·825	1·026	·994	1·075	1·197	1·016	1·201	1·271	1·045	1·048	·951	·917	1·049	1·134	·963	1·023	·969	1·042
1861	·936	·912	1·012	1·086	1·107	·930	1·050	1·163	1·083	·949	1·030	·870	1·011	1·071	·950	1·022	·979	1·039
1862	·909	·933	1·008	1·126	1·034	1·142	1·013	1·194	·948	1·108	·968	·917	1·025	1·076	·976	1·032	·984	1·023
1863	·912	·958	·996	1·153	1·021	1·150	1·063	1·098	1·103	·809	·907	·905	1·006	1·098	·913	1·033	·984	1·025
1864	·937	·970	1·131	1·056	1·230	1·173	1·076	1·082	1·027	1·031	1·021	·987	1·060	1·107	1·011	1·071	1·023	1·041
1865	·990	·998	1·042	1·102	1·115	1·269	1·157	1·178	·991	1·103	·989	·914	1·073	1·140	1·005	1·065	1·016	1·050
1866	·936	·972	1·118	1·168	1·073	1·236	1·106	1·183	1·035	·922	1·009	·980	1·062	1·133	·988	1·044	1·018	1·056
1867	·979	·940	1·096	1·101	1·163	1·058	1·056	1·230	·883	·844	1·063	·931	1·029	1·082	·972	1·055	1·031	1·061
1868	·952	·999	1·042	1·201	1·331	1·002	1·187	1·131	1·024	1·024	1·074	·988	1·080	1·146	1·093	1·077	1·027	1·058
1869	·862	·995	1·076	1·165	1·075	1·207	1·301	1·193	1·200	·942	·883	·854	1·062	1·190	·935	1·031	·952	1·048
1870	·889	·942	1·098	1·047	1·100	1·080	1·140	·893	1·069	1·015	1·024	·961	1·021	1·055	·978	1·017	·999	1·047
1871	·916	·850	1·100	1·144	1·074	1·076	1·077	1·066	1·071	1·079	·941	·920	1·026	1·085	·972	1·017	·982	1·035
1872	·849	1·022	1·025	1·138	1·119	·924	1·055	1·187	1·171	1·043	·932	·924	1·032	1·099	·987	1·071	·995	1·035
1873	·971	·962	1·091	1·091	1·059	1·171	1·255	1·088	1·033	1·021	1·064	·940	1·062	1·116	1·013	1·059	1·036	1·041
1874	·951	1·030	1·072	1·162	1·091	1·066	1·193	1·025	·936	1·090	·988	·938	1·045	1·079	·989	1·023	·987	1·012
1875	·890	·939	1·091	1·076	1·066	·970	1·269	1·064	1·141	·980	·914	·938	1·028	1·098	·958	1·063	·978	1·053
1876	·911	·992	1·017	1·095	1·222	1·203	1·276	1·197	1·095	1·000	·918	1·005	1·078	1·181	1·002	1·101	1·037	1·073
1877	·958	·997	1·132	1·213	·996	1·396	1·304	1·235	1·261	1·169	1·062	1·000	1·144	1·234	1·066	1·116	1·056	1·076
1878	1·032	1·042	1·090	1·110	1·220	1·123	1·046	1·111	·966	·968	1·031	·934	1·056	1·096	·987	1·051	1·025	1·082
1879	·959	·952	1·078	1·196	1·057	1·189	1·172	1·138	1·064	1·007	·896	·913	1·052	1·136	·958	1·048	·978	1·079
1880	·942	·981	1·011	1·123	1·073	1·186	1·243	1·065	1·113	1·006	1·027	1·027	1·066	1·134	1·030	1·099	1·066	1·070
1881	·910	1·052	1·157	1·222	1·136	1·129	1·343	1·216	1·107	1·105	·970	·932	1·107	1·192	·992	1·060	·982	1·068
1882	·911	1·039	·995	1·046	1·097	1·158	1·145	1·087	1·063	·995	1·085	·942	1·047	1·099	1·002	1·059	1·031	1·070
1883	1·002	·896	1·091	1·168	1·027	1·136	1·212	1·116	1·110	1·064	·990	·907	1·060	1·128	1·001	1·084	1·021	1·072
1884	·960	·990	1·095	1·184	1·185	1·076	1·330	1·069	1·071	1·056	1·040	·849	1·075	1·153	·998	1·087	1·029	1·076
1885	·996	·978	1·072	1·238	1·187	1·231	1·261	1·056	1·150	1·146	1·124	1·012	1·121	1·187	1·064	1·121	1·063	1·083
1886	·974	·988	1·138	1·143	1·186	1·561	1·180	·886	1·058	·972	1·036	·979	1·075	1·136	·979	1·032	1·018	1·084
1887	·893	·942	1·050	1·208	1·194	1·051	1·119	1·212	1·025	1·051	1·024	1·022	1·066	1·135	1·028	1·095	1·062	1·093
1888	·931	1·008	1·134	1·256	1·204	1·157	1·118	1·176	1·196	1·181	1·011	·972	1·112	1·184	1·044	1·097	1·037	1·078
1889	·984	1·004	1·109	1·144	1·174	·938	1·274	1·134	1·066	1·035	·920	·916	1·058	1·122	·975	1·045	1·004	1·068
1890	·931	·963	1·083	1·210	1·174	1·009	1·104	1·058	1·020	·844	1·034	·998	1·036	1·096	·991	1·075	1·059	1·079
1891	·932	1·026	1·112	1·250	1·298	1·132	1·195	1·218	1·150	1·032	1·080	·902	1·111	1·207	1·006	1·094	1·034	1·065
1892	·995	1·032	·996	1·201	1·151	1·182	1·191	1·032	·980	·976	·960	·952	1·054	1·123	·983	1·007	·984	1·056
1893	·930	·970	1·110	·984	·991	1·094	1·101	1·214	·965	·961	·980	·960	1·022	1·059	·979	1·051	1·012	1·063
1894	·914	1·058	1·000	1·162	1·192	1·114	1·098	1·078	1·130	1·004	1·060	·995	1·067	1·129	1·028	1·085	1·049	1·053
1895	·935	·991	1·186	1·126	1·272	1·172	1·068	1·032	·994	1·069	1·116	·884	1·070	1·111	1·007	1·043	1·005	1·059
1896	·942	·994	1·035	1·058	1·214	1·134	1·046	1·190	1·186	1·086	1·054	1·010	1·079	1·138	1·036	1·109	1·045	1·073
1897	·966	·990	1·110	1·142	1·180	1·202	1·188	1·119	1·068	·956	1·014	·981	1·076	1·150	·966	1·051	1·005	1·066
1898	·946	·850	1·048	1·189	1·218	1·102	1·128	1·200	1·050	·902	·901	·928	1·038	1·148	·912	1·048	·974	1·069
1899	·920	·986	1·013	1·096	1·176	1·114	1·290	1·238	1·161	1·082	·922	1·005	1·084	1·180	1·012	1·082	1·018	1·063
1900	·972	1·033	1·056	1·121	1·260	1·013	1·120	·900	1·150	1·039	1·026	·975	1·055	1·092	1·006	1·070	1·025	1·064
1901	·949	·990	1·058	1·154	1·238	1·110	1·257	1·133	1·026	1·039	1·064	·943	1·080	1·153	1·001	1·086	1·029	1·078
1902	·876	·986	1·099	1·204	1·250	1·189	1·233	1·302	1·055	1·020	1·016	·900	1·091	1·205	·992	1·069	·999	1·068
1903	1·027	·991	1·000	1·062	1·242	1·131	1·078	1·132	·952	1·022	·976	·918	1·044	1·100	·977	1·053	1·005	1·074
1904	·947	·898	1·104	1·186	1·184	1·090	1·230	1·171	1·113	·985	1·034	·959	1·075	1·162	·995	1·068	1·041	1·074
1905	·913	1·023	1·128	1·156	1·070	1·174	1·158	1·167	1·062	1·035	1·025	·990	1·078	1·131	1·000	–	–	–
1906	·946	·944	1·060	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 3.

PRESSURE.—MEAN MONTHLY VALUES.

—	Years.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean for Year.
		Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins	Ins.
Port Darwin	1878–1901	29·738	·750	·789	·840	·888	·921	·942	·930	·905	·870	·820	·769	29·847
Wyndham -	1889–1899	29·728	·762	·804	·892	·957	·988	30·017	30·000	29·931	·878	·823	·780	29·880
Derby -	1888–1899	29·750	·775	·828	·909	·990	30·007	30·032	30·016	29·970	·912	·860	·824	29·906
Cossack -	1890–1899	29·709	·744	·802	·932	30·008	30·029	30·068	30·048	29·994	·923	·854	·807	29·910
Alice Springs	1879–1901	29·816	·844	·993	30·104	·185	·218	·248	·206	·153	30·001	29·917	·851	30·042
Carnarvon -	1887–1901	29·789	·809	·886	·972	30·032	·043	·096	·096	·060	30·010	29·926	·858	29·965
Geraldton -	1886–1899	29·890	·898	·979	30·078	·110	·103	·150	·127	·103	30·069	29·999	·940	30·037
Perth - -	1885–1899	29·935	·954	30·024	·114	·116	·100	·144	·112	·094	·058	30·024	29·961	30·053
Bunbury -	1885–1899	29·960	·977	30·038	30·111	·107	·075	·115	·079	·076	·043	30·034	29·978	30·050
Sydney -	1859–1887	29·769	·801	·890	·935	·913	·931	·954	·927	·882	·830	·807	·742	29·865
Adelaide -	1857–1897	29·938	·980	30·070	·145	·140	·126	·164	·122	·069	·022	30·005	29·945	30·060
Melbourne -	1857–1899	29·834	·886	·967	30·025	30·018	29·972	30·021	29·976	·924	·882	·871	·821	29·933

TABLE 4.

RAINFALL.—MEAN MONTHLY VALUES.

—	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean for Year.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
West Australia:													
Shark's Bay District - -	·17	·39	·50	·62	1·09	3·23	2·40	1·45	·64	·30	·16	·04	11·48
Perth District - - -	·36	·58	·91	1·79	4·14	5·38	5·05	4·82	2·91	2·13	·95	·66	29·66
South Coast - - -	·71	·59	·77	1·01	1·72	2·27	1·77	1·91	1·33	1·20	·66	·44	14·39
South Australia:													
Eyre's Peninsula - -	·52	·37	·61	1·40	2·07	2·71	2·18	2·04	1·45	1·01	·53	·36	15·39
Agricultural District - -	·85	·60	·96	1·79	2·67	3·00	2·84	2·62	2·08	1·78	1·02	·89	21·10
Victoria - - - - -	1·80	1·35	1·97	2·77	3·51	4·04	3·60	3·70	3·25	2·95	2·20	1·93	33·09
West Australia:													
North-West - - -	4·07	1·87	2·89	1·23	·76	·76	·31	·23	0	0	·18	·73	13·03
North - - - - -	7·57	6·88	4·20	·83	·85	·40	·27	·06	·10	·33	1·70	4·37	27·44
South Australia:													
North - - -	12·26	10·35	8·49	2·25	·32	·06	·06	·04	·45	2·08	4·64	8·13	39·23
Queensland:													
North - - - -	12·82	14·45	10·45	10·13	2·33	·99	·76	·68	·71	1·26	4·28	4·61	63·50
South - - - -	7·18	6·14	5·58	2·91	2·59	2·42	1·83	1·46	1·86	2·19	2·81	4·04	40·92
Inland - - - -	4·43	3·05	2·75	2·32	1·49	1·12	·39	·45	·64	·71	1·28	1·23	19·47
South Australia:													
Central - - -	1·78	1·39	·89	·86	·89	·45	·19	·20	·27	·48	·69	·83	8·93
Lake Eyre District - -	·93	·70	·54	·71	·62	·65	·19	·44	·31	·33	·54	·52	5·18
New South Wales:													
Inland (N.E.) - - -	3·79	3·33	2·69	1·74	1·89	2·36	2·01	1·69	2·24	2·41	2·98	3·34	30·45
Coast - - - - -	4·90	6·44	5·66	5·39	6·00	5·49	4·54	3·40	3·72	3·17	4·03	4·62	57·34

Table 5.

RAINFALL.—TOTAL VALUES. (January to December.)

Year.	West Australia, Shark's Bay.	West Australia, Perth District.	West Australia, South Coast.	South Australia, Eyre's Peninsula.	South Australia, Pastoral.	Victoria.	South-West Australia, Summary
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1870	–	–	–	–	27·74	–	–
1871	–	–	–	–	23·55	–	–
1872	–	–	–	–	24·42	33·66	–
1873	–	–	–	–	20·87	27·81	–
1874	–		–	–	20·92	31·28	–
1875	–	–	–	–	26·60	33·71	–
1876	–	–	–	–	15·74	32·06	–
1877	–	23·71	–	–	21·92	28·30	–
1878	–	34·37	–	13·96	19·23	34·37	21·01
1879	–	25·61	–	14·66	20·54	29·91	22·31
1880	–	24·57	–	15·36	21·14	32·70	20·76
1881	–	22·50	–	11·85	18·13	29·36	16·17
1882	–	32·87	–	17·00	16·69	30·79	22·54
1883	–	31·20	–	19·48	24·07	31·09	23·19
1884	–	28·78	–	15·00	21·70	31·88	19·19
1885	–	30·23	14·73	17·25	17·64	31·13	20·99
1886	9·45	30·13	15·50	12·68	17·36	34·90	19·75
1887	11·11	33·83	16·76	18·12	23·39	34·83	23·55
1888	8·69	26·96	14·09	12·81	15·13	28·20	18·17
1889	18·53	35·99	15·09	21·95	30·22	36·52	26·04
1890	18·02	42·19	16·32	22·41	26·65	33·93	29·17
1891	5·15	25·33	13·81	13·14	16·13	28·16	18·00
1892	13·36	28·40	19·09	17·72	21·14	34·67	22·36
1893	16·37	36·42	16·92	20·30	24·67	33·98	26·26
1894	6·25	22·85	11·92	14·36	21·40	36·31	16·15
1895	12·86	33·31	9·67	16·13	19·71	33·44	21·61
1896	6·42	28·48	13·51	15·80	16·92	29·37	20·19
1897	11·52	27·03	9·95	11·05	15·91	28·61	16·45
1898	13·33	33·73	11·74	13·16	21·59	29·32	20·01
1899	11·37	31·78	12·25	12·94	17·20	34·98	21·13
1900	14·72	37·66	19·47	16·11	20·63	30·77	25·03
1901	9·64	28·07	15·23	17·58	18·26	27·58	22·06
1902	10·12	26·52	18·55	13·25	16·85	–	20·79
1903	14·72	37·47	15·44	16·32	23·81	–	24·51
1904	12·79	36·02	20·00	14·81	18·46	–	–
1905	13·11	35·91	12·83	10·81	21·92	–	–

TABLE 6.

RAINFALL.—TOTAL VALUES. (AUGUST TO JULY.)

——	West Australia, North.	South Australia, North.	Queensland, North-east.	South Australia, Central.	South Australia, Lake Eyre District.	New South Wales, Inland.	New South Wales, Coast.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1870–1871 - - -	–	–	–	–	–	–	–
1871–1872 - - -	–	–	–	–	–	21·79	37·65
1872–1873 - - -	–	–	–	–	–	33·77	76·80
1873–1874 - - -	–	43·63	–		–	27·71	71·74
1874–1875 - - -	–	49·01	–	–	–	28·60	59·68
1875–1876 - - -	–	45·12	–	–	–	30·60	61·98
1876–1877 - - -	–	49·58	–	16·97	–	–	45·12
1877–1878 - - -	–	38·86	–	8·78	–	23·82	57·42
1878–1879 - - -	–	52·97	–	15·57	–	40·63	55·16
1879–1880 - - -	–	41·03	–	10·58	–	31·52	57·42
1880–1881 - - -	–	31·26	–	3·50	–	21·49	45·58
1881–1882 - - -	–	40·29	–	8·19	–	23·61	48·82
1882–1883 - - -	–	38·40	–	4·21	3·26	28·47	58·03
1883–1884 - - -	–	39·53	–	5·62	3·50	22·35	48·26
1884–1885 - - -	–	42·22	–	11·33	7·53	23·48	44·00
1885–1886 - - -	–	39·30	–	5·51	3·11	23·31	45·86
1886–1887 - - -	–	46·79	–	14·73	7·77	41·15	71·01
1887–1888 - - -	29·73	41·56	–	6·57	4·08	22·77	53·04
1888–1889 - - -	26·83	39·57	–	13·42	8·68	28·48	56·32
1889–1890 - - -	31·52	47·88	–	8·98	7·30	43·12	96·93
1890–1891 - - -	19·04	42·01	–	10·34	4·98	35·98	60·12
1891–1892 - - -	17·62	24·84	–	5·70	2·14	36·98	67·97
1892–1893 - - -	25·15	39·13	–	7·92	4·34	52·98	68·07
1893–1894 - - -	19·92	42·82	–	12·19	4·51	33·75	47·00
1894–1895 - - -	27·24	50·24	–	15·05	9·11	24·48	57·04
1895–1896 - - -	34·68	51·72	–	7·10	3·62	26·24	43·38
1896–1897 - - -	15·92	39·16	39·57	5·37	4·19	25·32	43·72
1897–1898 - - -	29·45	60·48	65·88	8·50	4·65	30·58	55·65
1898–1899 - - -	49·24	54·20	52·76	6·17	4·01	22·18	50·33
1899–1900 - - -	18·05	28·26	31·73	6·56	2·20	30·17	88·41
1900–1901 - - -	16·12	44·92	49·75	6·61	2·61	17·46	45·26
1901–1902 - - -	23·38	35·22	40·27	2·72	–	18·78	31·86
1902–1903 - - -	38·38	33·22	69·38	13·00	–	–	–
1903–1904 - - -	36·51	60·01	62·04	11·61	–	–	–
1904–1905 - - -	16·26	38·29	44·84	7·06	–	–	–
1905–1906 - - -	–	–	31·30	–	–	–	–

Table 7.

RIVER GAUGES.—MEAN MONTHLY READINGS.

— —	Years.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean for Year.
		Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Bourke - .	1880–1902	4 9	8 7	12 2	8 7	6 5	6 8	10 0	11 10	9 11	7 2	6 4	4 7	8 1
Wilcannia .	1880–1902	6 9	9 2	13 7	11 5	8 6	7 9	10 6	13 2	11 11	10 7	9 0	7 2	10 0
Moama - -	1879–1902	5 0	3 0	1 10	2 9	4 4	9 6	15 8	16 10	19 8	18 6	15 2	9 6	10 2
Balranald -	1880–1902	4 2	3 0	2 3	2 4	3 0	4 10	8 9	9 8	11 6	12 2	10 7	7 6	6 9
Euston - -	1880–1902	10 1	6 4	4 6	5 0	10 4	8 7	13 1	16 1	17 9	19 0	17 9	14 3	11 11
Wentworth - -	1880–1902	7 8	5 9	5 0	5 1	5 5	7 4	10 0	12 6	13 0	14 9	14 0	11 7	9 4

TABLE 8.

RIVER GAUGES.—MEAN READINGS.*

Year.	January to December.						Year.	April to March.							
	Bourke.		Wilcannia.		Pooncarie.			Moama.		Balranald.		Euston.		Wentworth.	
	Ft.	in.	Ft.	in.	Ft.	in.		Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
1879	–		–		–		1879–1880	9	8	8	5	9	3	13	10
1880	6	6	9	7	13	4	1880–1881	13	6	8	1	10	10	12	1
1881	0	9	2	0	1	7	1881–1882	7	10	3	8	8	10	6	8
1882	3	5	4	5	6	0	1882–1883	8	11	4	9	7	3	7	5
1883	4	4	4	8	5	8	1883–1884	10	11	4	9	8	7	7	7
1884	0	9	1	6	1	10	1884–1885	5	8	3	6	5	9	4	10
1885	0	8	2	2	2	7	1885–1886	7	10	2	6	5	9	4	11
1886	16	3	16	1	11	1	1886–1887	7	10	5	8	6	3	9	5
1887	14	11	19	9	21	3	1887–1888	17	5	12	2	15	0	16	1
1888	3	2	5	1	6	9	1888–1889	8	10	4	5	6	8	7	3
1889	8	7	10	10	11	0†	1889–1890	16	3	9	10	15	4	14	0
1890	23	10	26	9	23	0	1890–1891	16	6	12	1	19	8‡	18	2
1891	18	3	23	8	23	9	1891–1892	10	1	10	5	15	8	14	0
1892	11	10	15	0	13	8	1892–1893	11	5	8	9	14	11	11	5
1893	19	7	23	11	25	2	1893–1894	14	7	11	0	17	10	14	9
1894	14	3	18	5	19	10	1894–1895	16	8	13	11	21	1	16	7
1895	3	0	6	2	6	11	1895–1896	9	3	5	2	12	7	8	5
1896	4	7	8	6	8	4	1896–1897	7	3	4	11	11	4	7	2
1897	9	1	7	6	7	0	1897–1898	6	3	3	3	9	8	6	3
1898	7	4	7	0	6	5	1898–1899	8	0	3	3	11	1	6	2
1899	4	6	4	0	3	9	1899–1900	7	6	4	2	10	3	5	6
1900	7	2	7	3	6	11	1900–1901	10	10	8	4	14	8	9	0
1901	2	8	3	10	3	5	1901–1902	8	3	4	11	10	11	5	7
1902	0	6	0	0½	0	1									

* In consequence of alteration in height of two gauges, the corresponding curves in Plate 5 are left broken.

† The gauge at Pooncarie was lowered 2 feet at the beginning of 1889.

‡ The gauge at Euston was lowered 4 feet 8 inches from the beginning of 1890.

Table 9.

RAINFALL.

Yearly Totals and Four-yearly Means.

Year.	Sydney, New South Wales.		Brisbane, Queensland.		Adelaide.		South Australia, Agricultural Districts.		Yanko, New South Wales.		Melbourne, Victoria.		Perth, Western Australia.		Horsham,* Victoria.	
	One Year.	Four Years.	One Year.	Four Years.	One Year.	Four Years.	One Year.	Four Years.	One Year.	Four Years.	One Year.	Four Years.	One Year.	Four Years.	One Year.	Four Years.
1840	58·52	—	29·32		24·23	—	—	—	—	—	22·57	—	—	—	—	—
1841	76·31	61·61	49·31	—	17·96	19·92	—	—	—	—	30·18	26·36	—	—	—	—
1842	48·82	64·61	28·82	—	20·32	18·09	—	—	—	—	31·16	27·78	—	—	—	—
1843	62·78	61·07	51·23	—	17·19	18·31	—	—	—	—	21·54	26·22	—	—	—	—
1844	70·67	59·83	63·21	—	16·88	19·95	—	—	—	—	28·26	26·06	—	—	—	—
1845	62·03	54·83	59·19	—	18·83	22·55	—	—	—	—	23·93	28·22	—	—	—	—
1846	43·83	51·95	31·43	—	26·88	23·27	—	—	—	—	30·53	29·45	—	—	—	—
1847	42·80	41·82	—	—	27·61	24·92	—	—	—	—	30·18	34·53	—	—	—	—
1848	59·17	42·08	42·59	—	19·75	23·09	—	—	—	—	33·15	33·64	—	—	—	—
1849	21·48	40·16	—	—	25·44	23·88	—	—	—	—	44·25	—	—	—	—	—
1850	44·88	36·32	—	—	19·56	25·82	—	—	—	—	26·98	—	—	—	—	—
1851	35·14	42·48	—	—	30·86	26·24	—	—	—	—	—	—	—	—	—	—
1852	43·78	38·58	—	—	27·44	25·18	—	—	—	—	—	—	—	—	—	—
1853	46·11	43·00	—	—	27·09	23·26	—	—	—	—	—	—	—	—	—	—
1854	29·28	42·90	—	—	15·34	22·63	—	—	—	—	—	—	—	—	—	—
1855	52·85	44·10	—	—	23·15	20·89	—	—	—	—	28·21	—	—	—	23·22	—
1856	43·31	51·68	—	—	24·93	22·12	—	—	—	—	29·75	28·22	—	—	21·91	22·00
1857	50·95	48·98	—	—	20·15	19·95	—	—	—	—	28·90	26·62	—	—	20·80	18·36
1858	59·60	58·85	43·00	—	20·25	18·34	—	—	—	—	26·01	25·53	—	—	16·03	17·04
1859	42·06	60·71	35·00	50·52	14·46	19·31	—	—	—	—	21·82	25·59	—	—	14·66	16·87
1860	82·81	51·80	54·63	46·83	18·50	19·71	—	—	—	—	25·38	24·61	—	—	16·67	15·80
1861	58·36	53·06	69·44	55·29	24·04	22·01	27·83	—	—	—	29·16	28·26	—	—	20·14	18·03
1862	23·98	49·61	28·27	53·38	21·85	22·33	21·76	21·10	—	—	22·08	28·76	—	—	11·71	17·52
1863	47·08	41·12	68·82	42·05	23·67	20·19	27·98	21·31	22·80	—	36·42	25·46	—	—	23·61	15·00
1864	69·12	47·32	47·00	47·78	19·75	19·76	18·83	21·34	24·28	18·67	27·40	25·54	—	—	14·64	15·80
1865	36·29	50·48	24·11	45·84	15·50	18·60	16·68	20·17	6·11	17·41	15·94	22·88	—	—	10·01	14·50
1866	36·81	48·96	51·18	43·08	20·11	18·66	21·86	20·64	21·49	14·47	22·41	20·60	—	—	14·89	13·61
1867	59·68	46·93	61·04	50·65	19·05	18·47	23·31	20·68	17·76	17·39	25·79	22·76	—	—	18·42	13·84
1868	43·05	53·78	35·98	57·62	19·99	19·40	20·70	22·15	12·53	21·02	18·27	25·60	—	—	11·09	16·97
1869	48·19	51·93	54·39	53·72	14·74	20·45	16·85	22·21	17·78	21·39	24·58	26·70	—	—	10·97	18·77
1870	64·22	50·45	79·06	57·03	23·84	21·12	27·74	23·14	36·00	23·32	33·77	30·26	—	—	27·42	20·86
1871	52·27	56·75	45·45	58·94	23·25	22·69	23·55	24·14	19·25	22·98	30·17	30·51	—	—	25·60	21·29
1872	37·12	56·60	49·22	48·85	22·66	21·03	21·42	22·44	20·21	16·34	32·52	29·10	—	—	19·45	21·31
1873	73·40	55·09	62·02	54·24	21·00	22·52	20·87	23·20	16·42	17·49	25·60	29·77	—	—	20·68	19·53
1874	63·60	57·23	38·71	55·29	17·23	20·22	20·92	21·04	9·44	15·48	28·10	27·65	—	—	19·50	18·48
1875	46·25	53·80	67·03	47·36	29·21	21·21	26·60	21·29	23·87	14·80	32·87	27·28	—	—	18·48	16·41
1876	45·69	50·34	53·42	51·76	13·43	22·42	15·74	20·87	12·20	17·78	24·04	26·59	28·73	—	15·27	15·53
1877	59·66	54·58	30·28	51·81	24·95	20·29	21·92	19·36	13·68	15·67	24·10	23·19	20·49	32·57	12·39	14·39
1878	49·77	50·53	56·33	50·76	22·08	22·55	19·23	20·71	21·37	16·32	25·36	24·30	39·71	33·33	15·97	14·02
1879	63·19	45·89	67·30	50·53	20·69	20·82	20·54	19·76	15·45	17·01	19·28	24·30	41·34	34·41	13·94	14·16
1880	29·51	44·02	49·12	47·11	22·48	19·22	21·14	19·12	14·79	18·17	28·48	23·56	31·79	33·40	13·78	13·81
1881	41·09	39·95	29·39	38·44	18·02	20·74	18·13	20·01	16·44	14·99	24·08	24·67	21·78	32·97	12·96	15·78
1882	42·28	43·58	42·62	36·93	15·70	19·81	16·69	20·15	16·01	13·99	22·40	24·01	35·65	33·02	14·55	16·19
1883	46·92	43·29	32·22	36·29	26·76	19·27	24·07	20·02	12·71	13·74	23·71	24·72	39·58	35·18	21·83	16·70
1884	44·04	42·57	43·49	39·05	18·74	18·95	21·70	20·19	10·78	13·26	25·85	25·12	31·96	33·49	15·41	18·00
1885	39·91	45·88	26·85	51·38	15·89	18·69	17·64	20·02	15·45	17·80	26·94	27·29	33·44	32·95	15·02	17·33
1886	39·43	40·63	53·66	48·78	14·42	17·64	17·36	18·38	14·11	17·48	24·00	25·69	23·90	31·92	19·76	16·27
1887	60·16	44·94	81·54	54·41	25·70	21·38	23·39	21·52	30·86	19·77	32·39	25·74	37·52	33·55	19·14	19·18
1888	23·01	55·44	33·08	59·25	14·55	24·23	15·13	23·85	9·51	20·64	19·42	25·79	27·83	38·01	11·17	19·55
1889	57·16	54·22	49·36	49·28	30·87	21·30	30·22	22·03	24·59	18·56	27·14	24·37	39·96	36·21	25·64	18·75
1890	81·42	65·78	73·02	57·26	25·78	23·05	26·65	23·54	17·61	20·25	24·20	24·69	46·73	37·06	21·27	20·80
1891	55·30	63·97	41·68	66·98	14·01	20·70	16·13	22·15	22·53	17·81	26·73	24·60	30·33	37·10	15·91	19·63
1892	69·26	53·17	64·97	59·73	21·53	19·45	21·14	21·34	16·26	19·13	24·69	25·20	31·23	31·35	18·98	19·67
1893	49·90	47·31	88·26	64·09	21·49	21·27	24·67	22·23	14·84	17·29	26·80	22·78	40·12	32·02	22·35	19·36
1894	38·22	40·59	44·02	59·09	20·78	19·68	23·40	21·17	22·91	16·77	22·60	22·90	23·72	32·09	21·43	15·15
1895	31·86	38·75	59·11	47·66	21·28	18·16	19·71	18·99	15·14	15·86	17·04	22·66	33·01	28·87	14·69	15·41
1896	42·40	39·99	44·98	51·67	15·17	18·16	16·92	18·54	14·18	12·67	25·16	20·91	31·50	30·95	12·12	14·73
1897	42·52	46·00	42·53	46·23	15·42	17·55	15·92	17·91	11·22	11·76	25·85	23·87	27·25	30·69	13·39	15·01
1898	43·17	52·03	60·08	43·59	20·75	19·17	21·59	18·83	10·13	12·63	15·61	24·60	32·04	31·96	18·73	16·50
1899	55·90	51·44	37·35	42·58	18·84	19·82	17·20	19·42	11·50	12·70	28·87	25·00	31·96	34·36	15·80	16·82
1900	66·54	51·41	34·41	31·61	21·68	18·64	20·63	18·23	17·66	12·43	28·09	26·87	36·61	33·09	18·07	14·68
1901	40·15	47·10	38·49	34·59	18·01	20·29	18·26	19·89	11·50		27·45	26·76	36·75	34·03	14·69	
1902	43·07	41·94	16·17	34·30	16·02	19·95	16·85	19·34	8·88	—	23·08	27·17	27·06	33·46	10·18	—
1903	38·62	40·66	49·28	33·86	25·47	21·02	23·81	20·26	—	—	28·43	26·72	35·69	32·93	—	—
1904	45·93	37·87	33·24	40·53	20·51	23·64	18·46		—	—	29·72	26·52	34·35		—	—
1905	35·03		36·76		22·28		21·92	—	—	—	25·64		34·61	—	—	—
1906	31·89	—	42·85	—	26·51	—	—		—		22·29	—	—		—	

* 1855–1868 inclusive at Walmer, 3 miles away. 1869–1873 inclusive at Longernong, 11 miles away. 1874 and onwards at Horsham.

TABLE 10.

PRESSURE.

Year.	Cordoba, 720 mm. + Year.	Cordoba April–Sept.	Cordoba Four Years.	Cape Town, 29 ins. + Year.	Cape Town April–Sept.	Cape Town Four Years.	Durban, 30 ins. + Year.	Durban April–Sept.	Durban Four Years.	Batavia, 750 mm. + Year.	Batavia April–Sept.	Batavia Four Years.	Bombay, 29 ins. + Year.	Bombay April–Sept.	Bombay Four Years.
1841	–	–	–	–	1·115	–	–	–	–	–	–	–	–	–	–
1842	–	–	–	1·036	1·089	–	–	–	–	–	–	–	–	–	–
1843	–	–	–	1·046	1·111	1·043	–	–	–	–	–	–	–	–	–
1844	–	–	–	1·033	1·112	1·043	–	–	–	–	–	–	–	–	–
1845	–	–	–	1·057	1·127	1·041	–	–	–	–	–	–	–	–	–
1846	–	–	–	1·036	1·093	1·033	–	–	–	–	–	–	–	–	–
1847	–	–	–	1·036	1·089	1·026	–	–	–	–	–	–	·792	·694	–
1848	–	–	–	1·004	1·067	1·019	–	–	–	–	–	–	·800	·710	·797
1849	–	–	–	1·027	1·083	1·016	–	–	–	–	–	–	·793	·690	·797
1850	–	–	–	1·009	1·061	1·024	–	–	–	–	–	–	·803	·718	·797
1851	–	–	–	1·023	1·088	1·029	–	–	–	–	–	–	·791	·692	·801
1852	–	–	–	1·038	1·095	1·039	–	–	–	–	–	–	·800	·707	·800
1853	–	–	–	1·047	1·123	1·047	–	–	–	–	–	–	·809	·705	·807
1854	–	–	–	1·049	1·123	1·048	–	–	–	–	–	–	·799	·699	·807
1855	–	–	–	1·052	1·121	1·046	–	–	–	–	–	–	·819	·730	·805
1856	–	–	–	1·043	1·115	1·043	–	–	–	–	–	–	·801	·700	·807
1857	–	–	–	1·039	1·105	1·036	–	–	–	–	–	–	·803	·705	·804
1858	–	–	–	1·039	1·096	1·031	–	–	–	–	–	–	·807	·711	·804
1859	–	–	–	1·024	1·086	1·025	–	–	–	–	–	–	·807	·717	·801
1860	–	–	–	1·023	1·080	1·014	–	–	–	–	–	–	·799	·710	·793
1861	–	–	–	1·016	1·080	1·016	–	–	–	–	–	–	·792	·695	·789
1862	–	–	–	·993	1·035	1·017	–	–	–	–	–	–	·778	·692	·796
1863	–	–	–	1·031	1·110	1·022	–	–	–	–	–	–	·787	·685	·799
1864	–	–	–	1·030	1·096	1·033	–	–	–	–	–	–	·827	·739	·809
1865	–	–	–	1·035	1·101	1·035	–	–	–	–	–	–	·806	·708	·817
1866	–	–	–	1·036	1·112	1·038	–	–	–	8·84	8·82	–	·817	·726	·818
1867	–	–	–	1·038	1·102	1·038	–	–	–	8·85	8·57	8·97	·819	·710	·819
1868	–	–	–	1·043	1·103	1·032	–	–	–	9·20	9·35	8·80	·831	·747	·813
1869	–	–	–	1·034	1·108	1·028	–	–	–	8·99	8·91	8·71	·809	·714	·808
1870	–	–	–	1·013	1·098	1·021	–	–	–	8·14	8·28	8·45	·792	·708	·798
1871	–	–	–	1·024	1·087	1·016	–	–	–	8·49	8·72	8·32	·800	·719	·797
1872	–	–	–	1·013	1·078	1·023	–	–	–	8·20	8·34	8·43	·790	·701	·800
1873	3·74	4·65	–	1·013	1·072	1·026	·073	·145	–	8·46	8·49	8·41	·806	·713	·803
1874	4·72	6·01	4·38	1·044	1·134	1·035	·102	·179	·099	8·57	8·48	8·53	·805	·703	·811
1875	4·75	6·51	4·42	1·032	1·108	1·040	·110	·175	·108	8·43	8·67	8·85	·812	·717	·821
1876	4·32	5·56	4·37	1·052	1·119	1·036	·110	·191	·104	8·65	8·68	8·88	·819	·722	·820
1877	3·88	5·08	4·27	1·032	1·088	1·035	·109	·182	·097	9·77	9·75	8·82	·848	·768	·818
1878	4·52	5·96	4·14	1·029	1·096	1·034	·089	·148	·090	8·68	8·68	8·85	·801	·708	·819
1879	4·36	5·73	4·09	1·029	1·091	1·039	·081	·163	·084	8·17	8·30	8·63	·805	·713	·813
1880	3·79	5·24	3·98	1·048	1·125	1·042	·083	·159	·088	8·79	8·81	8·60	·822	·732	·816
1881	3·72	5·36	3·86	1·050	1·139	1·041	·084	·159	·093	8·87	8·97	8·78	·825	·735	·818
1882	4·05	5·83	3·88	1·042	1·119	1·042	·106	·173	·100	8·57	8·50	8·84	·811	·716	·820
1883	3·90	5·79	3·95	1·026	1·086	1·036	·101	·157	·104	8·90	8·96	8·92	·816	·719	·821
1884	3·85	5·12	4·12	1·049	1·123	1·031	·110	·198	·103	9·01	9·04	8·89	·830	·729	·821
1885	4·02	5·47	4·19	1·028	1·079	1·035	·101	·161	·111	9·21	9·10	8·79	·828	·734	·823
1886	4·72	6·56	4·19	1·022	1·076	1·031	·102	·183	·108	8·45	8·36	8·83	·812	·719	·824
1887	4·17	5·26	4·33	1·043	1·109	1·052	·133	·219	·112	8·50	8·72	8·72	·821	·738	·821
1888	3·86	4·79	4·32	1·029	1·073	1·034	·097	·148	·113	9·15	9·01	8·77	·836	·740	·821
1889	4·57	6·08	4·31	1·035	1·106	1·031	·116	·195	·108	8·79	8·65	8·93	·815	·714	·823
1890	4·69	6·44	4·54	1·029	1·093	1·028	·105	·181	·098	8·64	8·69	8·74	·810	·720	·810
1891	4·11	5·40	4·70	1·030	1·095	1·024	·113	·184	·092	9·16	9·31	8·67	·830	·742	·810
1892	4·79	7·20	4·73	1·018	1·087	1·023	·059	·137	·093	8·36	8·61	8·69	·787	·693	·808
1893	5·23	6·69	4·75	1·019	1·084	1·019	·091	·166	·088	8·52	8·50	8·58	·812	·720	·805
1894	4·79	6·39	4·64	1·024	1·162	1·024	·108	·190	·100	8·71	8·76	8·76	·805	·708	·813
1895	4·21	5·69	4·54	1·017	1·092	1·031	·094	·170	·101	8·72	8·82	8·83	·817	·730	·812
1896	4·34	5·48	4·34	1·037	1·098	1·031	·107	·178	·097	9·08	9·14	8·72	·818	·726	·809
1897	4·82	6·68	4·13	1·045	1·124	1·034	·095	·181	·101	8·80	8·94	8·78	·808	·711	·813
1898	4·00	5·51	4·02	1·026	1·099	1·030	·094	·199	·100	8·30	8·55	8·75	·795	·710	·814
1899	3·35	4·04	3·80	1·029	1·095	1·029	·121	·224	·107	8·95	9·05	8·78	·830	·748	·817
1900	3·93	5·21	3·69	1·022	1·080	1·028	·092	·176	·104	8·97	8·90	8·99	·824	·734	·823
1901	3·91	4·79	3·95	1·039	1·106	1·032	·112	·210	·093	8·92	8·80	8·93	·820	·730	·817
1902	3·57	4·47	3·96	1·023	1·060	1·036	·082	·130	·093	9·12	9·13	8·87	·818	·720	·816
1903	4·36	5·78	4·06	1·046	1·102	–	·086	·165	·089	8·71	8·67	8·96	·807	·706	·819
1904	3·96	4·70	4·34	1·037	1·102	–	·094	·176	–	8·74	8·85	–	·818	·725	·818
1905	4·37	4·97	4·45	–	–	–	·093	·148	–	9·27	9·20	–	·833	·742	·819
1906	4·69	5·90	–	–	–	–	–	–	–	–	–	–	·815	·716	–
1907	4·87	6·42		–	–		–	–		–	–		·809	·726	

ADDENDUM.

ADDENDUM.

Further Discussion on the Latitudes of Australian Anticyclones.

While the mean annual (January to December) values for the latitudes of the anticyclones, as given by Russell, have a variation of 2·8 degrees between the two extreme values, it was considered more advisable to form the monthly values into two groups according to the seasons. This procedure was adopted as it seemed possible that changes might be occurring in the seasons which might neutralise each other, and therefore not be apparent in the mean for the year. This inquiry has led one to conclude that a law is possibly in operation which, if corroborated, may prove of considerable importance.

If, for instance, the year be divided into the two seasons, April to September (winter), when the anticyclones in their annual movement have a low mean latitude, and October to March (summer), when the anticyclones are in higher latitudes, it is found that the mean latitudes of the centres of the tracks are for each season respectively as follows:—

Table 1.

Mean Latitudes of Anticyclone Centres.

——	April–September (Winter).	October–March (Summer).
	° ′	° ′
1888–1889	30 40	37 10
1889–1890	30 40	37 20
1890–1891	30 30	34 10* minimum.
1891–1892	32 40* maximum	35 50
1892–1893	31 30	39 20
1893–1894	32 30	40 10
1894–1895	30 10	36 10* minimum.
1895–1896	32 10* maximum	37 0
1896–1897	31 30	36 20
1897–1898	32 30	36 20
1898–1899	33 10	34 50* minimum.
1899–1900	36 10* maximum	36 20
1900–1901	32 40	—
Mean	32 4	36 45
Difference	4° 41′	

On examining the second and third columns of figures, it will be noticed that the *maxima* in column 2 seem to be closely associated with the *minima* in column 3. Thus the maxima for the winter months in 1891, 1895, and 1899 follow closely after the minima of the preceding summer months in 1890–1891, 1894–1895, and 1898–1899. The values referred to have been marked with an asterisk.

Similarly, the *minima* in column 2 for the winter months of 1890, 1894, and 1896 are closely associated with the *maxima* in the third column for the preceding summer months, 1889–1890, 1893–1894, and 1895–1896.

The only outstanding values which do not conform to the above-mentioned rule are those for April–September in 1892 and 1893.

Summarising the results brought together in the above table, it is seen that at the epochs 1890–1891, 1894–1895, and 1898–1899 there is a great tendency of

the range of anticyclones in latitude to be at a minimum, while, on the other hand, at the epochs 1889–1890, 1893–1894, and 1895–1896 the range attains a maximum. There is thus a variation in range of latitude of about four years duration.

This variation is shown graphically in the accompanying illustration (Fig. 11).

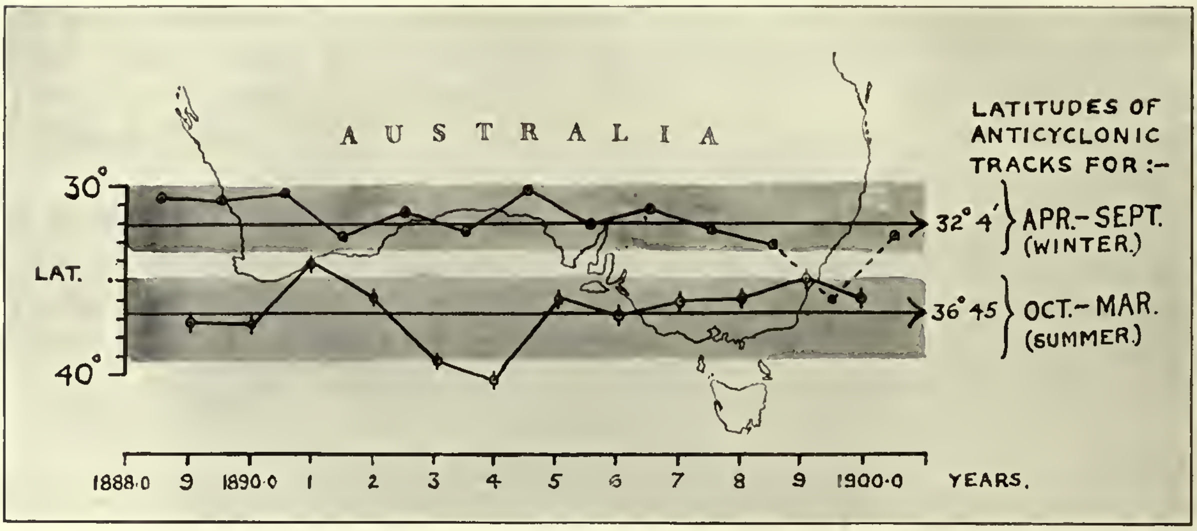


Fig. 11.

The upper large arrow represents the direction and mean track of the anticyclones for the winter months for the period 1888–1900, while the lower arrow represents the direction and mean track for the summer months for the same period. These values are 32° 4′ and 36° 45′ S. latitude respectively, as seen from Table 1. The coast line of Australia is also shown to indicate the relation of these mean tracks to the continent.

With a horizontal scale of years given at the bottom the individual values for the latitudes for each of the seasons for each year, as given in columns 2 and 3 of Table 1, are plotted. For each season a belt can be drawn to include most of the variations in the different years from the mean value, and each of those belts has been shaded to render them more apparent.

It will be noticed that when the points are above the mean line in the winter months they are for the most part below the mean line for the summer months, and *vice versâ*. This shows that when the tracks of the anticyclones in the winter seasons are in lower latitudes than usual, those for the summer seasons are in higher latitudes, and *vice versâ*. Thus there is an inclination for the annual swing of the anticyclonic track to be small in some years and large in others.

This diagram shows further that there is much less evidence of the anticyclonic belt as a whole being in some years more north or more south. If such a movement were in operation, then, when the points were above the winter mean line, the corresponding points should be above the summer mean line. That this is not the case can be seen at a glance, especially for the last four years, where the values for the winter seasons are below and those for the summer seasons above the mean lines.

The detection of this change of range of the paths of the anticyclones, showing that in some years the range between summer and winter was large and in other years small, led one to inquire in what way the variation was associated with pressure differences between the two seasons.

A comparison was therefore made between the range anomalies and those of pressure in the following way:—

In Table 1 the means of each of the second and third columns were formed (namely, 32° 4′ and 36° 45′) and their difference (4° 41′) determined. This difference is considered as the mean change of latitude due to the two seasons.

To eliminate this the differences between columns 3 and 2 have been determined for each epoch, and the mean value (4° 41′) subtracted from each, thus resulting in a column of anomalies with positive and negative signs, the positive signs denoting large ranges and the negative small ranges of latitude change. Further, the winter group of months (April to September) for each year was considered in relation to the preceding and following summer months (October to March) separately, and in this way two columns of variations from the mean formed, one for the twelve months April to March and the other for October to September.

Exactly the same procedure was adopted with the monthly pressure values at Adelaide. The winter and summer mean pressures were determined for each year and the means for the period 1888 to 1900 formed. The differences between the winter and summer values were then separately found, and the differences from the mean for the whole period determined.

In this way two sets of range anomalies were obtained, one representing the changes for the consecutive group of 12 months April to March and the other the changes for the months October to September. The "plus" signs indicate large and the "minus" signs small ranges of pressures.

These values are placed in columns 3 and 5 in Table 2, while the figures representing the anomalies of the range in latitude of the anticyclones are given in columns 2 and 4 of the same table.

The values thus obtained are as follows:—

TABLE 2.

—	Range in Latitude Anomalies, April-March.	Adelaide, Pressure Anomalies, April-March.	Range in Latitude Anomalies, Oct.-Sept.	Adelaide, Pressure Anomalies, Oct.-Sept.
	° ′	Inches.	° ′	Inches.
1888–1889 - -	+ 1 49	+ 0·003	+ 1 49	– 0·059
1889–1890 - -	+ 1 59	+ 0·010	+ 2 9	– 0·016
1890–1891 - -	– 1 1	– 0·032	– 3 11	+ 0·079
1891–1892 - -	– 1 31	+ 0·064	– 0 21	– 0·020
1892–1893 - -	+ 3 9	+ 0·003	+ 2 9	– 0·061
1893–1894 - -	+ 2 59	– 0·057	+ 5 19	+ 0·013
1894–1895 - -	+ 1 19	– 0·036	– 0 41	– 0·054
1895–1896 - -	+ 0 9	– 0·033	+ 0 49	– 0·006
1896–1897 - -	+ 0 9	– 0·035	– 0 51	– 0·023
1897–1898 - -	– 0 51	+ 0·047	– 1 31	+ 0·045
1898–1899 - -	– 3 1	+ 0·067	—	+ 0·101
1899–1900 -	– 4 31	+ 0·031	– 1 1	– 0·057

A comparison of columns 2 and 3 shows that there is a great tendency for positive anomalies in the ranges in latitude (plus signs in column 2) to be associated with negative pressure anomalies (minus signs in column 3) and *vice versâ*. A similar, but not so clearly indicated, result is seen when the values in columns 4 and 5 are compared.

Having thus shown that between the two seasons there seems to be a tendency for large ranges of latitude to be associated with small ranges in pressure, an attempt was made to find out how these changes were related to high or low pressure years.

The summer and winter Adelaide pressure values were therefore treated separately. For each season, summer and winter, in the period 1888 to 1900 the mean values of pressure were formed, and the differences from the mean for the period determined.

Two series of values were thus obtained, the one showing excess (+) or deficient (—) pressure for the summer months, and the other for the winter months. These values were then compared with those of columns 2 and 4 in Table 2, and are reproduced below in Table 3.

TABLE 3.

—	Range in Latitude Anomalies, April-March.	Pressure, Adelaide. Difference from Mean, April-Sept.	Range in Latitude Anomalies, Oct.-Sept.	Pressure, Adelaide. Difference from Mean, Oct.-March.
	° ′		° ′	
1888–1889 - -	+ 1 49	+ 0·050	+ 1 49	+ 0·047
1889-1890 - -	+ 1 59	— 0·012	+ 2 9	— 0·022
1890–1891 - -	— 1 1	— 0·038	— 3 11	— 0·006
1891–1892 - -	— 1 31	+ 0·073	— 0 21	+ 0·009
1892–1893 - -	+ 3 9	— 0·011	+ 2 9	— 0·014
1893–1894 - -	+ 2 59	— 0·075	+ 5 19	— 0·018
1894–1895 - -	+ 1 19	— 0·005	— 0 41	+ 0·031
1895–1896 - -	+ 0 9	— 0·023	+ 0 49	+ 0·010
1896–1897 - -	+ 0 9	+ 0·004	— 0 51	+ 0·039
1897–1898 - -	— 0 51	+ 0·016	— 1 31	— 0·031
1898–1899 - -	— 3 1	+ 0·014	—	— 0·055
1899–1900 - -	— 4 31	+ 0·046	— 1 1	+ 0·015

Now, when we come to compare the signs in columns 2 and 3, it will be seen that plus signs in the former are, on the whole, associated with negative signs in the latter, and *vice versâ*. The conclusion to be drawn, therefore, is that when the pressure during the winter months is in excess the range of latitude of the anticyclones during the winter and the following summer is small.

If columns 4 and 5 in Table 3 be examined, it will be noticed that there is a tendency also for large ranges in latitude to correspond to low pressures, and *vice versâ*.

It has been previously shown (page 20) that years of excessive high pressure are those when anticyclones are exceptionally large and of great intensity. It is, therefore, quite possible that their magnitude, and in consequence of their movement their driving power, renders them less liable to be moved from their mean track, and explains possibly the smallness of the latitude change at those epochs.

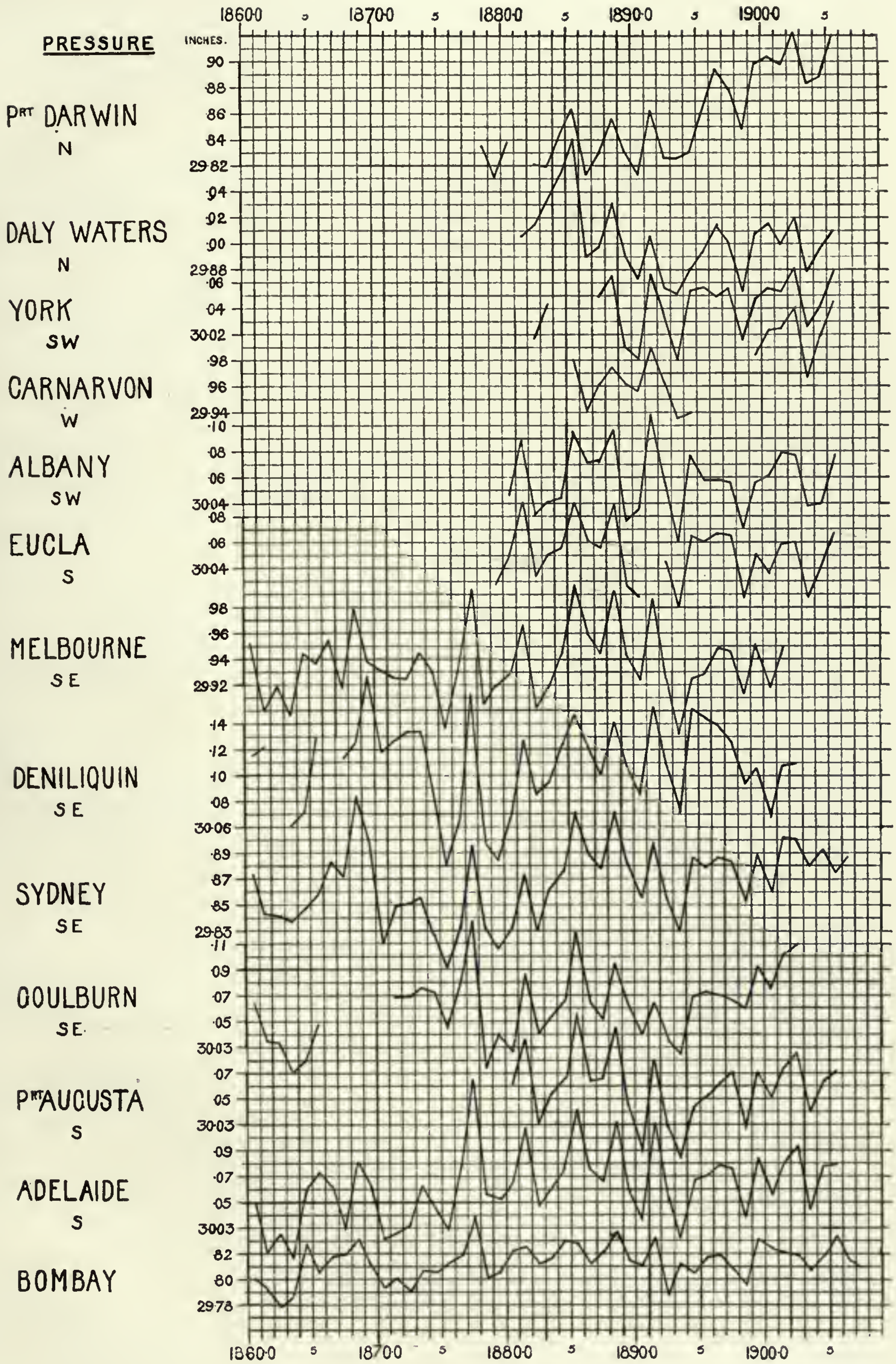
In other years, when the pressure is deficient, they would not be so liable to be restricted, and, consequently, their range in latitude might be greater.

Summing up, then, the conclusions drawn from the examination of the monthly mean latitude of the anticyclones for the period 1888 to 1900 as given by Russell, it may be stated—

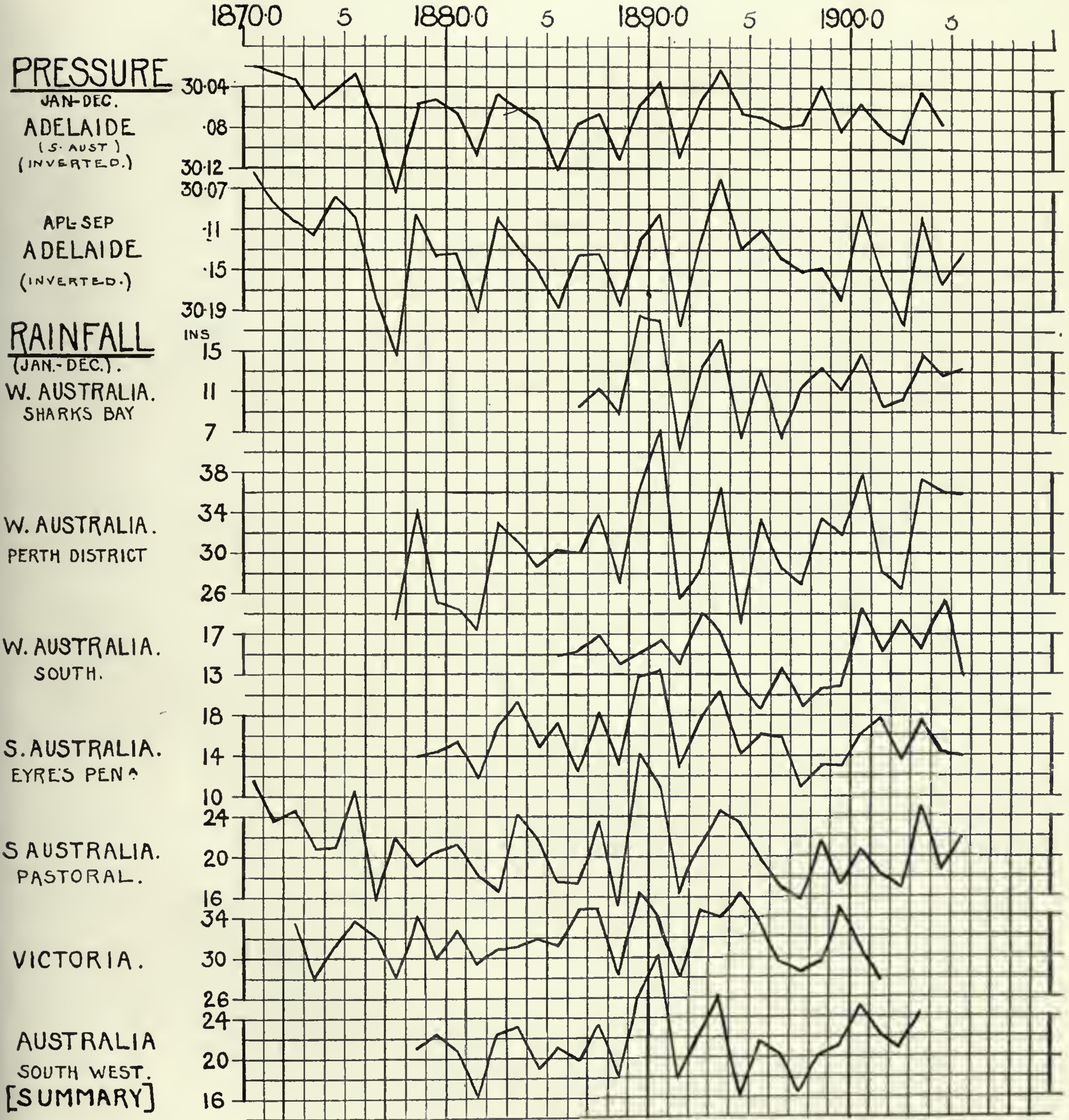
(*a*) That years of low pressure are years when the seasonal range of pressure is small, and when the seasonal range of latitude of the paths of the anticyclones is large.

(*b*) That years of high pressures are associated with years when the seasonal pressure range is large, and the seasonal latitude range of the paths of the anticyclones is small.

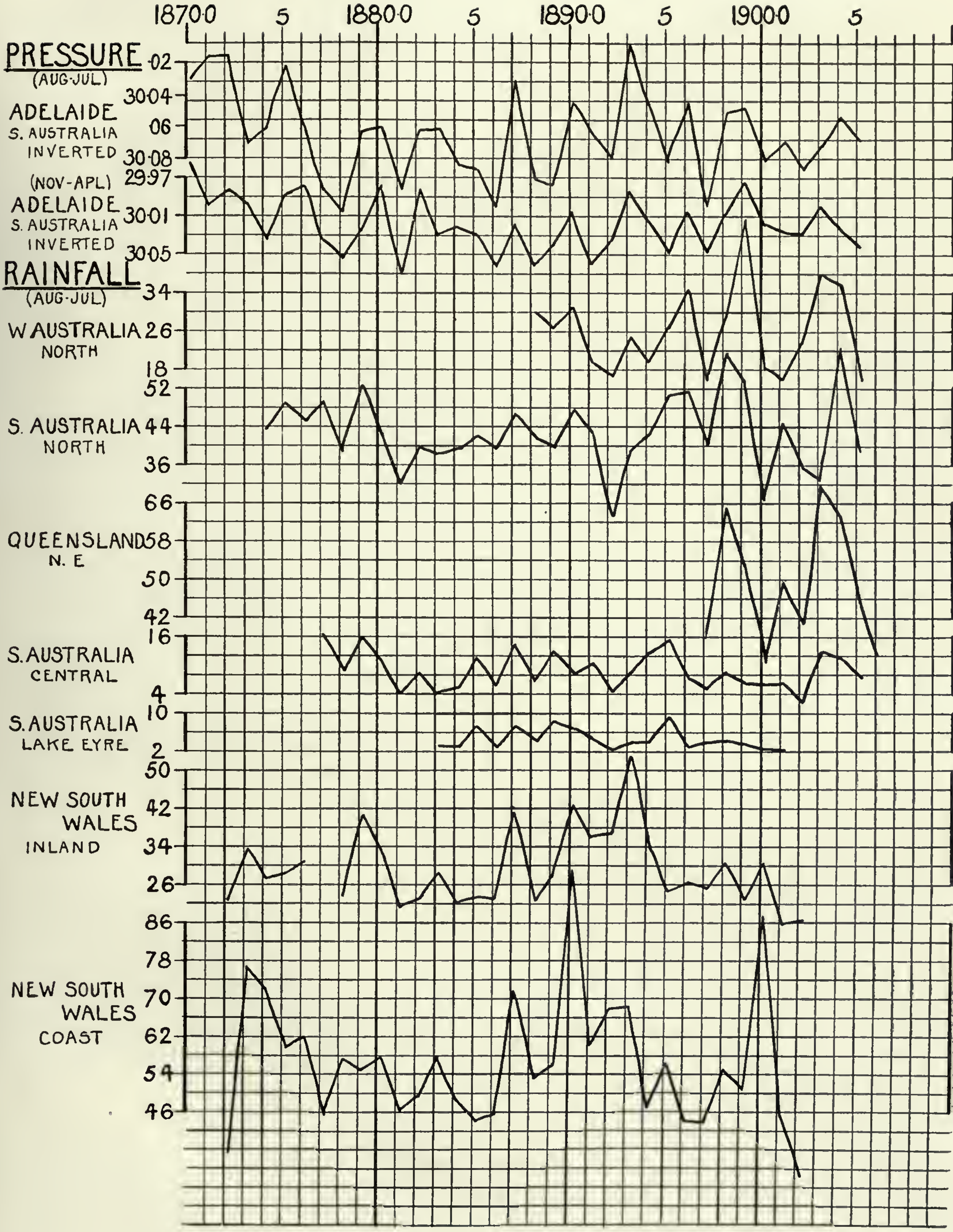
The length of time over which the observations discussed above is, however, so short that the above conclusions must only be looked upon as tentative. Should more recent data corroborate the inferences drawn, an interesting and important feature of Australian meteorology will have been discovered.


PRESSURE
INCHES.
1860·0
1870·0
1880·0
1890·0
1900·0
Prt DARWIN
N
DALY WATERS
N
YORK
SW
CARNARVON
W
ALBANY
SW
EUCLA
S
MELBOURNE
SE
DENILIQUIN
SE
SYDNEY
SE
GOULBURN
SE
PrtAUGUSTA
S
ADELAIDE
S
BOMBAY

See page 9.

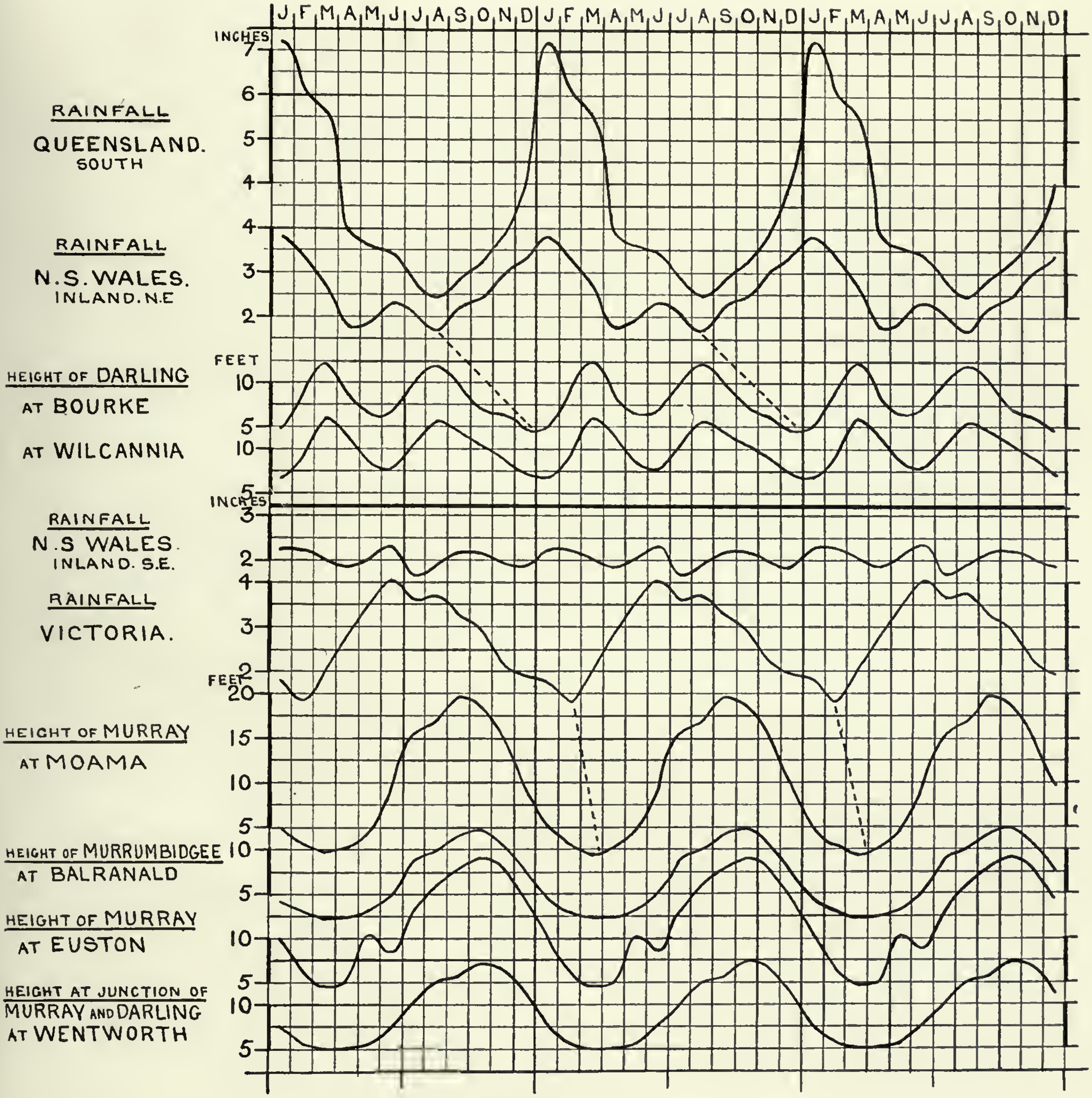

1870·0
5
1880·0
5
1890·0
5
1900·0
5
PRESSURE
JAN-DEC.
ADELAIDE
(S. AUST)
(INVERTED.)
30·04
·08
30·12
30·07
APL-SEP
ADELAIDE
(INVERTED.)
·11
·15
30·19
RAINFALL
(JAN.-DEC.).
INS
W. AUSTRALIA.
SHARKS BAY
15
11
7
38
W. AUSTRALIA.
PERTH DISTRICT
34
30
26
W. AUSTRALIA.
SOUTH.
17
13
S. AUSTRALIA.
EYRE'S PENA
18
14
10
S AUSTRALIA.
PASTORAL.
24
20
16
VICTORIA.
34
30
26
AUSTRALIA
SOUTH WEST.
[SUMMARY]
24
20
16

See page 46.

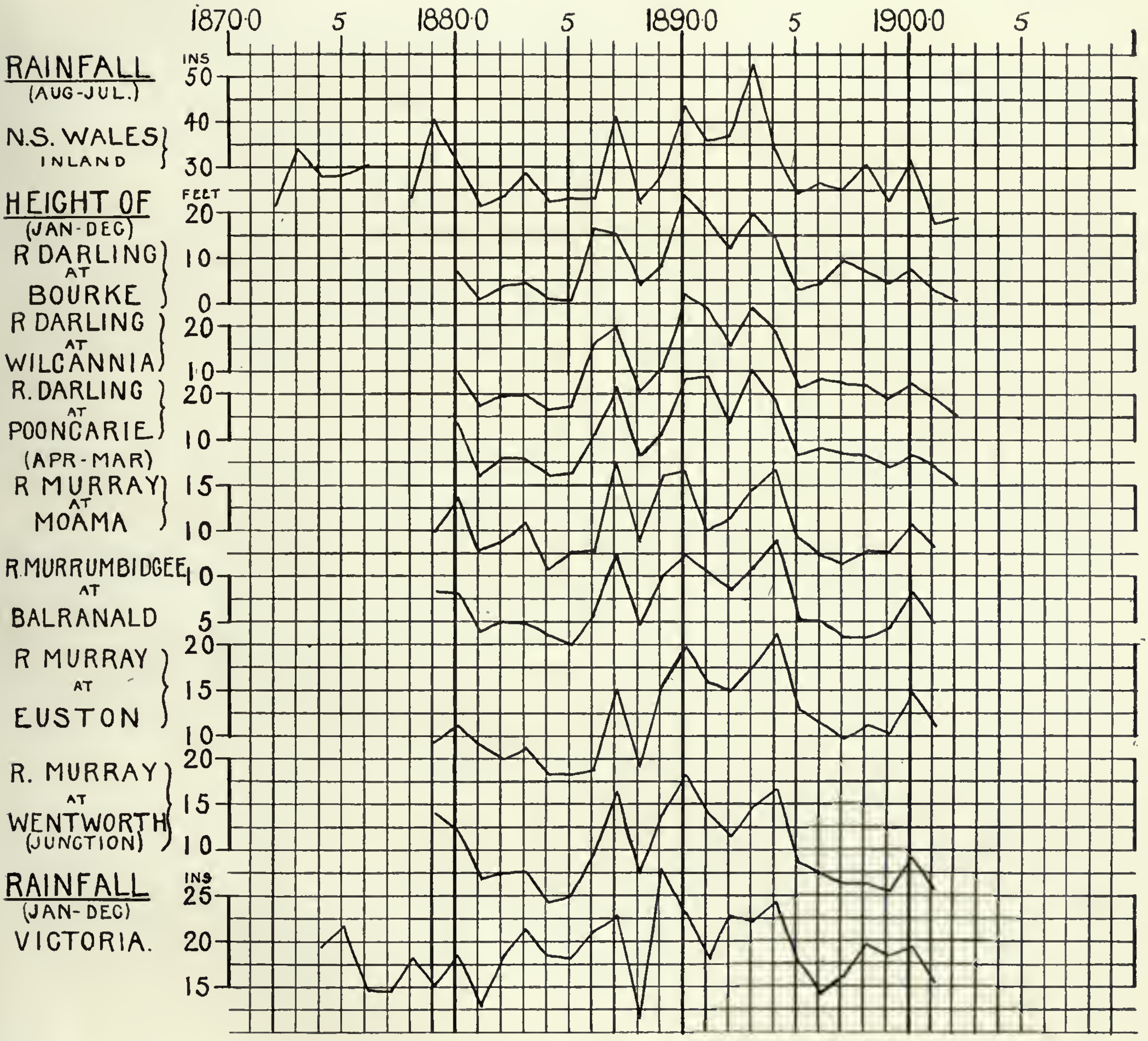

1870·0
5
1880·0
5
1890·0
5
1900·0
5
PRESSURE
(AUG-JUL)
ADELAIDE
S. AUSTRALIA
INVERTED
·02
30·04
·06
30·08
(NOV-APL)
ADELAIDE
S. AUSTRALIA
INVERTED
29·97
30·01
30·05
RAINFALL
(AUG-JUL)
W AUSTRALIA
NORTH
34
26
18
S. AUSTRALIA
NORTH
52
44
36
QUEENSLAND
N. E
66
58
50
42
S. AUSTRALIA
CENTRAL
16
4
S. AUSTRALIA
LAKE EYRE
10
2
NEW SOUTH
WALES
INLAND
50
42
34
26
NEW SOUTH
WALES
COAST
86
78
70
62
54
46

See page 47.

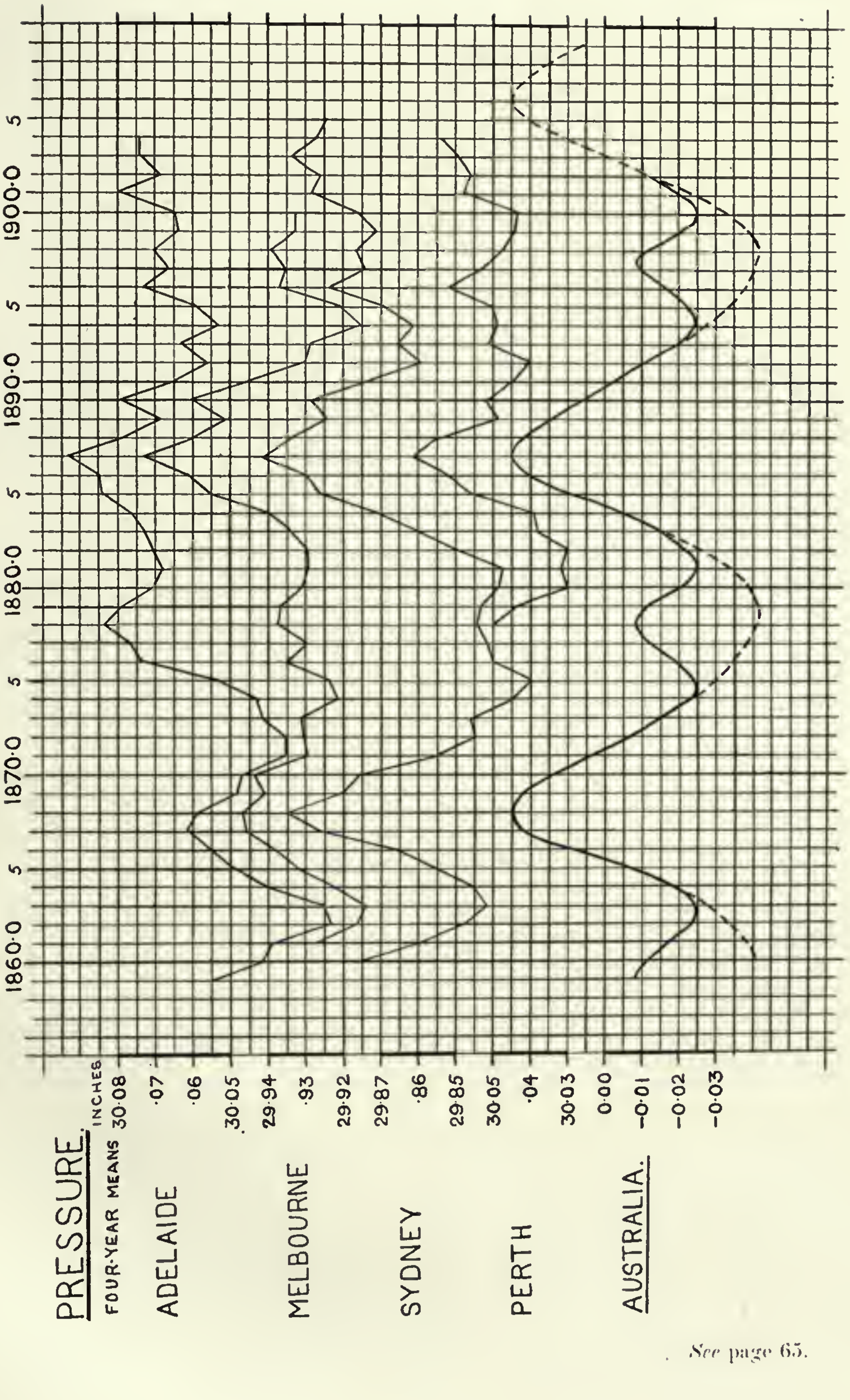
PLATE 4.



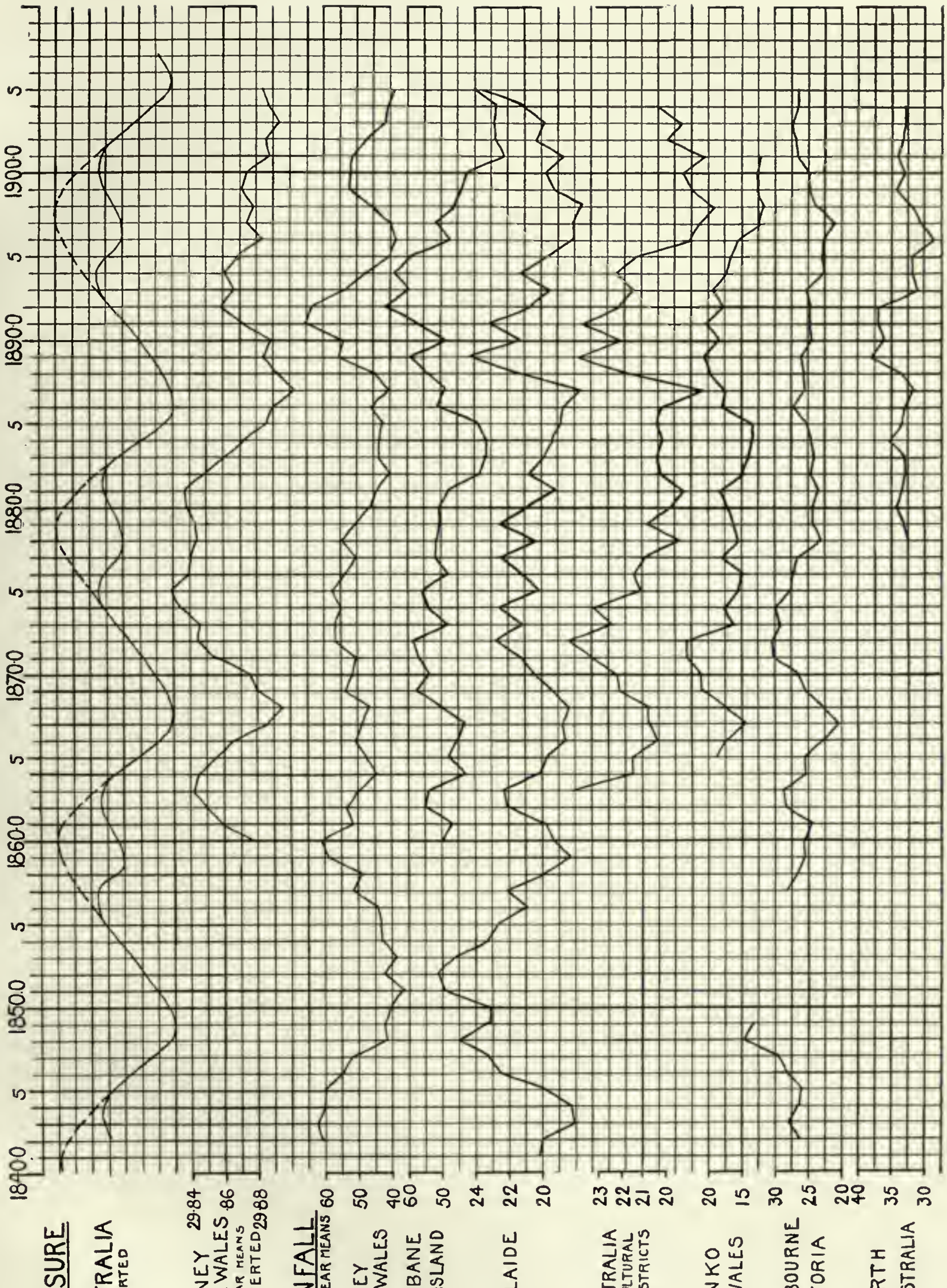
See page 58.


1870·0
5
1880·0
5
1890·0
5
1900·0
5
RAINFALL
(AUG-JUL.)
N.S. WALES
INLAND
INS
50
40
30
HEIGHT OF
(JAN-DEC)
FEET
R DARLING AT BOURKE
20
10
0
R DARLING AT WILCANNIA
20
10
R. DARLING AT POONCARIE
(APR-MAR)
20
10
R MURRAY AT MOAMA
15
10
R.MURRUMBIDGEE AT BALRANALD
10
5
R MURRAY AT EUSTON
20
15
10
R. MURRAY AT WENTWORTH (JUNCTION)
20
15
10
RAINFALL
(JAN-DEC)
VICTORIA.
INS
25
20
15

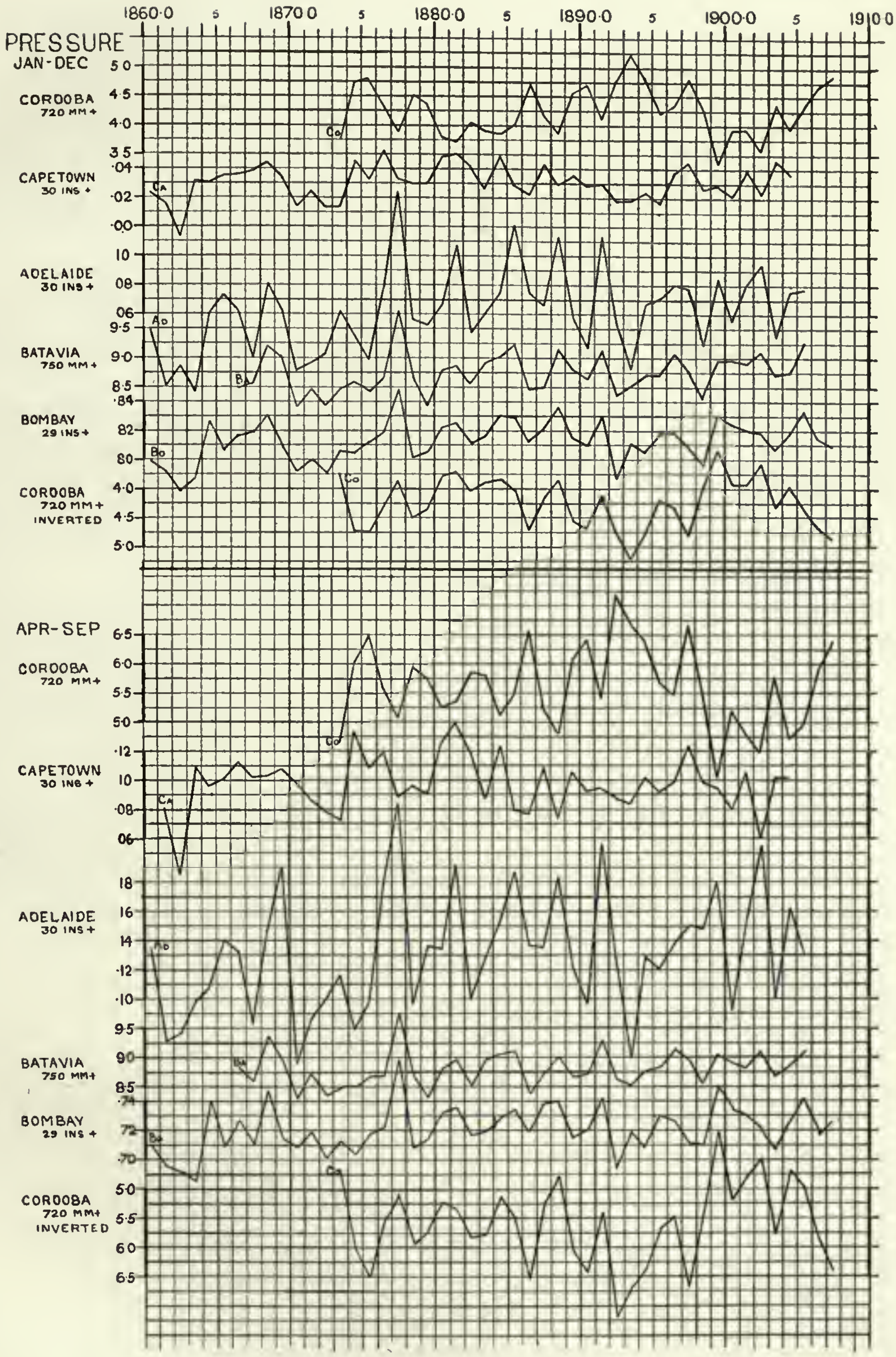
See page 59.


PRESSURE.
FOUR-YEAR MEANS
INCHES
ADELAIDE
MELBOURNE
SYDNEY
PERTH
AUSTRALIA.
30·08
·07
·06
30·05
29·94
·93
29·92
29·87
·86
29·85
30·05
·04
30·03
0·00
−0·01
−0·02
−0·03
1860·0
5
1870·0
5
1880·0
5
1890·0
5
1900·0
5

See page 65.


PRESSURE
AUSTRALIA INVERTED
SYDNEY N.S.WALES FOUR-YEAR MEANS INVERTED
29·84 ·86 29·88
RAINFALL FOUR-YEAR MEANS
SYDNEY N.S.WALES
60 50 40
BRISBANE QUEENSLAND
60 50
ADELAIDE
24 22 20
S.AUSTRALIA AGRICULTURAL DISTRICTS
23 22 21 20
YANKO N.S.WALES
20 15
MELBOURNE VICTORIA
30 25 20
PERTH W.AUSTRALIA
40 35 30
1840·0 5 1850·0 5 1860·0 5 1870·0 5 1880·0 5 1890·0 5 1900·0 5

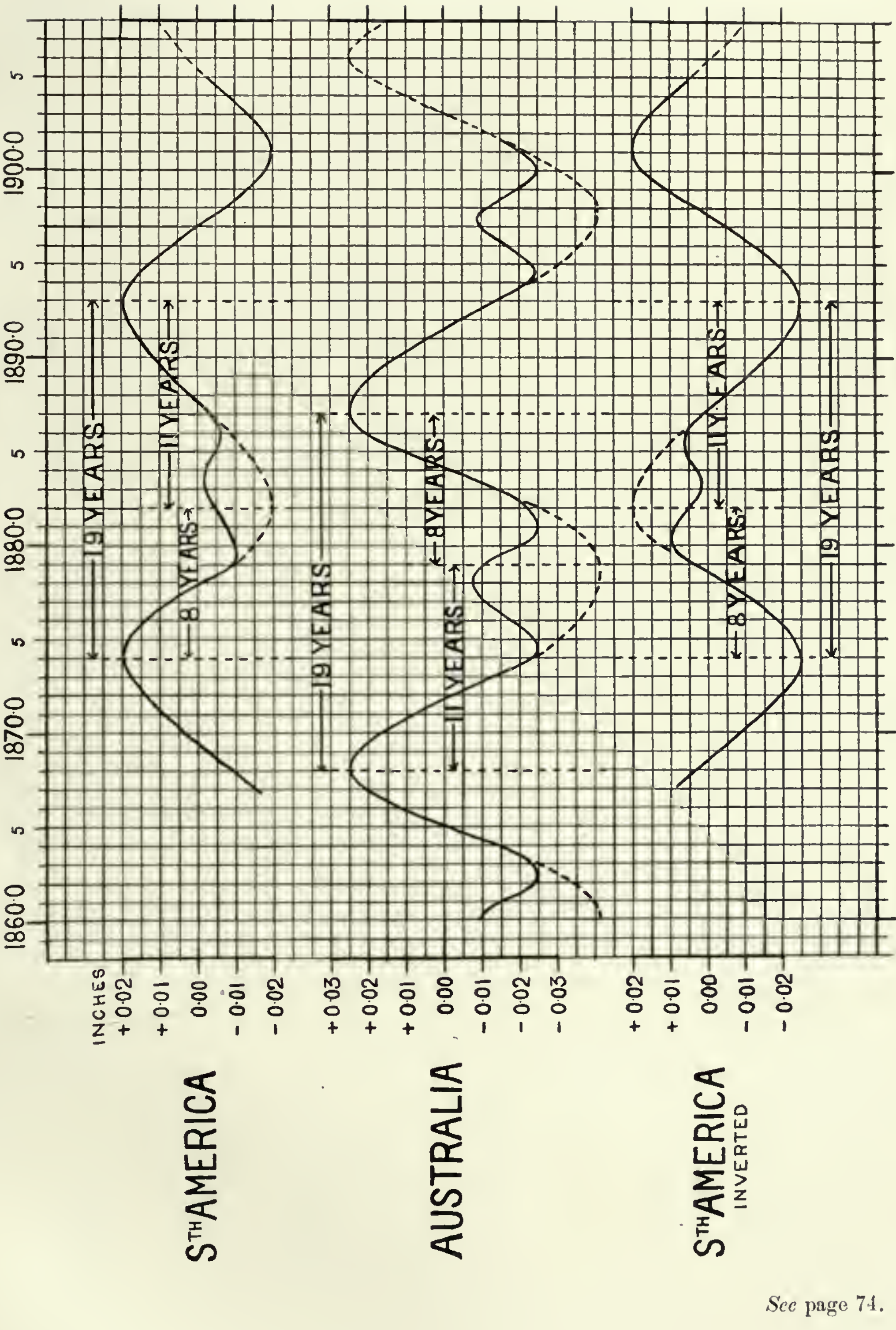
See page 67.



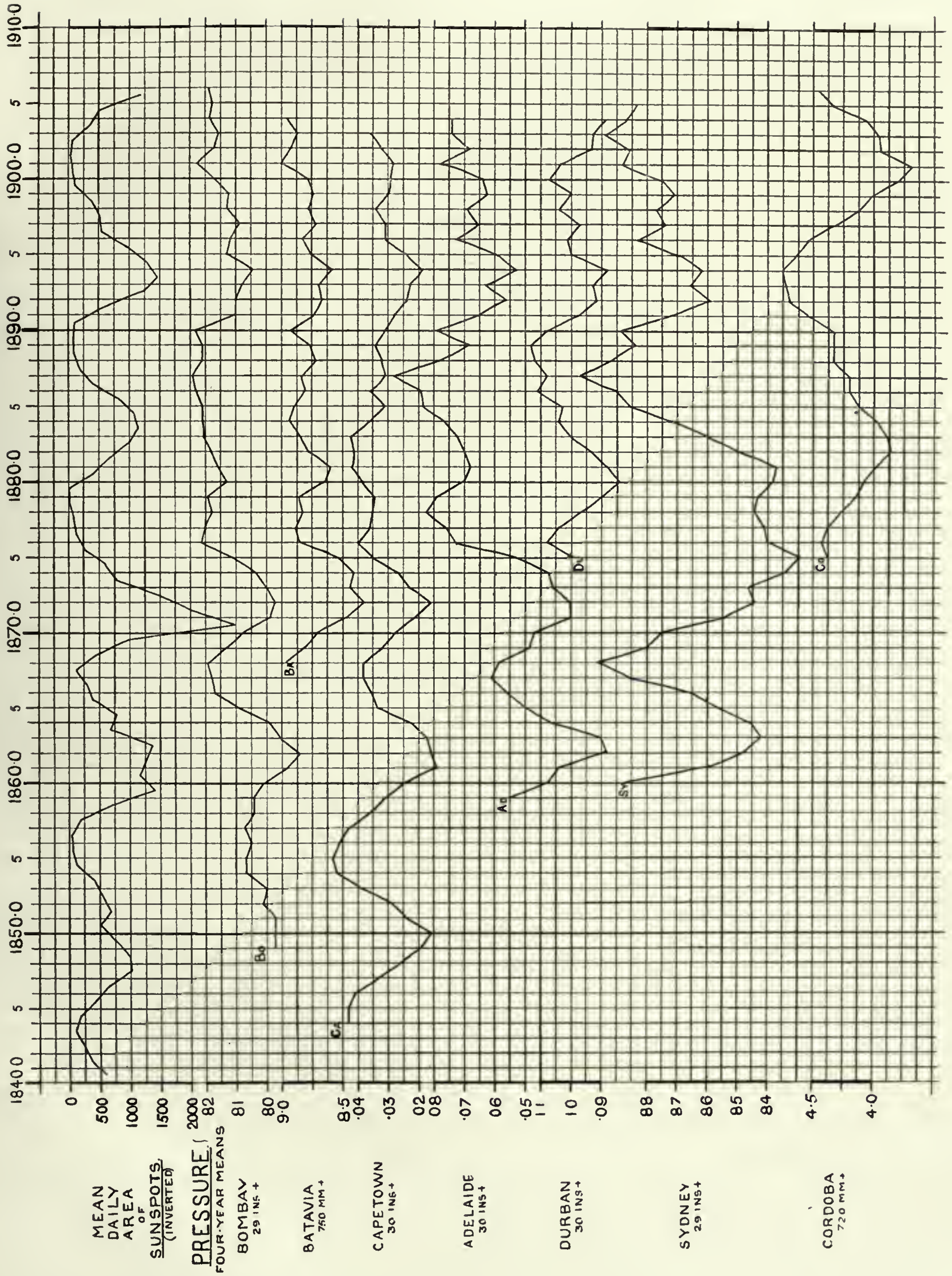
1860·0
1870·0
1880·0
1890·0
1900·0
1910·0
PRESSURE
JAN-DEC
CORDOBA
720 MM +
CAPETOWN
30 INS +
ADELAIDE
30 INS +
BATAVIA
750 MM +
BOMBAY
29 INS +
CORDOBA
720 MM +
INVERTED
APR-SEP
CORDOBA
720 MM +
CAPETOWN
30 INS +
ADELAIDE
30 INS +
BATAVIA
750 MM +
BOMBAY
29 INS +
CORDOBA
720 MM +
INVERTED

See page 72.

PLATE 9.



See page 74.


MEAN DAILY AREA OF SUNSPOTS (INVERTED)
PRESSURE FOUR-YEAR MEANS
BOMBAY 29 INS +
BATAVIA 750 MM +
CAPETOWN 30 INS +
ADELAIDE 30 INS +
DURBAN 30 INS +
SYDNEY 29 INS +
CORDOBA 720 MM +
1840·0
1850·0
1860·0
1870·0
1880·0
1890·0
1900·0
1910·0

See page 75.